JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXV. FEBRUARY, 1888. No. 2.

THE FRANKLIN INSTITUTE is not responsible for the statements and opinions advanced by contributors to the JOURNAL.

THE STRONG LOCOMOTIVE.

BY GEORGE S. STRONG.

(FIRST PAPER.)*

JOSEPH M. WILSON, President, in the chair.

MR. STRONG:—This locomotive has been the outgrowth of a preconceived determination of its designer and inventor, to overcome the radical and well recognized defects existing in locomotives of ordinary construction, while retaining all the admirable qualities to be found in the running gear and minor parts.

Much discussion has taken place in the last few years regarding the possibilities of the future, as to fast train service, and much ink has been wasted, without any practical results, in stating what could and what could not be accomplished. It still remains a

* Read before the FRANKLIN INSTITUTE, Wednesday, March 16, 1887.

fact, that there is no regular scheduled train to-day on the American Continent, or in England, or in Europe, that travels at a speed of sixty (60) miles per hour, for any considerable distance. We hear of fast runs being made occasionally, but when we come to make enquiries, we find that it has been with a very light train, or for a very short distance.

The *Railroad Gazette*, of February 11, 1887, speaking of a recent locomotive turned out by one of our Eastern builders, intended for very high speed, and in questioning the ability of the locomotive to do the work for which it was intended, says: *

"The locomotive in question is specially designed to run a train regularly at a higher speed than has ever been attained before. A speed of forty miles per hour, including stops, is a high speed on a first-class line, and is rarely attained for any distance in regular running. Special trains are, of course, often run at higher speed, but the rate of forty miles per hour, including stoppages, can only be maintained with any punctuality in daily running when the circumstances are favorable, the train not inordinately heavy, the grades and curves easy, and the average distance between stoppages at least thirty miles. When the train has to slack frequently at drawbridges or railroad crossings, such a speed cannot be maintained. The fact that such speeds are only attained by a very small number of trains in this country, shows the difficulty of maintaining a high velocity for a considerable distance. The fastest train on the New York Central runs from New York to Buffalo, 440 miles, in ten hours and forty-five minutes, or at the rate 40·93 miles per hour. This can be done because the grades are remarkably favorable, and the stopping stations average no less than 110 miles apart. The Pennsylvania runs the limited express from Jersey City to Pittsburgh, 443 miles, in eleven hours and seventeen minutes, corresponding to a speed of 39·27 miles per hour, the average distance between stoppages being 110·34 miles. The speed is fully one and one-half miles slower than on the New York Central, showing the effects of the more unfavorable grades and curves. On a straighter track, the Pennsylvania attains a considerably higher speed, the fastest train between Jersey City and Washington covering the distance, 226·7 miles, in five hours and two minutes, which gives a speed of

* This engine has since been acknowledged a failure, and has never run over the line intended for it. (S.)

45·04 miles per hour. The distance from New York to Boston by the Boston and Albany route is 234 miles, and notwithstanding the keen competition and great through travel, the speed is only thirty-nine miles per hour by the fastest train on this route, which covers the distance in six hours.

"The fastest runs in regular work between any two stopping points give a speed of slightly over fifty-three miles per hour. Higher rates of speed have been obtained when making up time, but at present the average speed while in motion seems to be considerably under sixty miles per hour. Many trains doubtless fully attain that speed on a large portion of the run, but the time occupied in getting up speed after starting, and slackening before stopping, reduces the average speed to about fifty-three miles per hour.

"These figures show the highest speeds attained on this continent for any considerable distance, and clearly demonstrate that the speed proposed on the New York, Providence and Boston, 62·5 miles in 62·5 minutes—including a stop at a drawbridge—is altogether exceptional in regular running.

"The principal peculiarity of the engine that is to run at this exceptional speed is the enormous weight on the drivers, 72,000 pounds. Why such a weight should be necessary to attain a high speed is somewhat of a mystery. Adhesion is very necessary to enable an engine to start a train or to haul a heavy train up a steep grade, but complaints about engines slipping at high speed are seldom heard. The difficulty is more generally the impossibility of getting the required speed out of the engine. In whatever position the reverse lever may be placed, the engine will not run to time. The reason has often been pointed out in these columns, and consists in the fact that at excessive speeds the steam is so wiredrawn in passing through the ports that the steam line is attenuated, and sufficient pressure cannot be put on the piston to overcome the resistance of the train. The back pressure, too, is greatly increased, still further diminishing the size of the diagram. These difficulties can, however, be overcome in great measure by using slide valves with the Allen internal passage and large ports and exhaust nozzle. The more serious difficulty of making steam then remains, and can only be overcome by a liberal allowance of heating surface."

As to the question of the Allen valve being able to help them

out, the writer is led to believe, from experiments made with the indicator, and from the experience of some leading lines where this valve is used along with other valves, that little benefit is to be derived from its use, as it does not help the locomotive where it is the weakest, *i. e.*, on the exhaust side of the piston.

When we seek for the reasons we find that to run a very heavy train at a very high speed, for any considerable distance, takes a very large power, and a continuous development of that power. To obtain this we must have a very high mean effective pressure on the piston, and this must be maintained during the journey.

When we examine the link motion, we find it is not well adapted to give this high mean effective pressure without making a very heavy draught on the boiler. If we then go to the boiler, examine its construction and calculate its capacity for economical evaporation of the necessary quantity of steam from cold water, we find it is not well adapted for burning the large amount of coal required to evaporate this quantity of water. We also find that it is not well adapted to carry the pressure demanded. It is therefore evident that the boiler, valve gear and valves are found wanting, and that these are the vital parts of any locomotive. A high mean effective pressure is absolutely essential, and anything which tends to hinder the attainment of this is a weak point in the design or construction of a locomotive intended for heavy and fast train service.

The price paid in obtaining this much desired end must be carefully considered. This price consists of first cost, coal consumption, running expenses and maintenance of the locomotive and all its parts.

Let us see what are the necessary conditions to secure great economy of coal, steam of high pressure, and the use of this steam to the best advantage. There are certain well-known laws which control the production and burning of gases from coal, whether it be anthracite or bituminous, and if these conditions are complied with, complete combustion is as certain as the burning of gunpowder, or the combination of any elements which have an affinity for one another. If these conditions are not complied with, complete combustion cannot be expected. These laws are so well understood that it is hardly necessary to go into their explanation here; all that is required is, a grate of ample area to

first distil a sufficient quantity of gases from the coal, in a given time, to produce the necessary quantity of work. In a locomotive where 1,200 to 1,500 horse-power is required this cannot be done, as it could be in a gas producer, and a partial combustion goes on as the gas is produced; the grate, however, must be large enough to permit the coal to be burned on it without any being carried over and through the tubes. The second step and essential condition is the uniting of the gas so produced with a quantity of heated air large enough to cause complete combustion, and to maintain a temperature sufficiently high to ignite and burn the mixture of air and gas. Enough time must be allowed for a complete mixture to take place, before the gases or products of combustion go to the tubes in which combustion cannot take place, but where the heat generated by combustion is utilized and reduced.

In designing a boiler to meet these conditions, we have combined some very novel features, and have made use of the highest development of both the steel makers' and the boiler makers' art. This is emphatically the age of steel, and with it we entered on a new era in the art of boiler making, and the manipulation of steel plates. We are able to do things now, that a few years ago would have been regarded as impossible, and even now are so regarded, except by a few leaders who are always to be found with the courage of their convictions.

We have also taken advantage of well-known mechanical principles in designing shapes as near as possible to those that Nature would make, if she were undertaking work of this kind. That is, we have done away with all flat and square forms, to resist pressure by transverse strength alone, and have adopted those that give the greatest resistance against internal as well as against external pressures. We have also banished all stays and crown bars, and as a result we have a boiler that is not only strong, but one that will always remain so, and when finished and ready for work, will always be ready and not a constant source of expense and annoyance.

It will be readily understood from an examination of the accompanying illustrations, that the outer shell of the boiler is, as nearly as may be, the shape it would take if it were made of canvas, and then inflated. Therefore, under full working pressure it

is of the same shape as when it has no pressure on, and the metal in all parts of the shell is under direct tensile strains, there being no tending to bend the sheets. There can be no tendency to crystallize, and the parts should last as long as the natural life of the steel in other structures under similar light tensile strains, providing there is no corrosion going on. The factor of safety in the boiler illustrated is five.

The interior part of the boiler is so clearly shown as scarcely to require description. Departures from the ordinary construction call for a word of explanation: There are two fire chambers, discharging the gases generated in them over a hollow bridge, where they receive the supply of heated air necessary to cause complete combustion, and by alternate firing an incandescent fire is always maintained on one side to burn the gas from the opposite fire-chamber where coal has last been charged. The air which is to mingle with the gases is heated by the hollow grate bars and hollow bridge, and as a very thin fire is carried, air can pass up through it readily.

The fire chambers or furnaces are welded and corrugated steel cylinders, joined on to the combustion chamber by a welded and corrugated steel junction piece. This piece may be made of one plate formed on dies in a hydraulic press and flanged out to join the ends of the fire and combustion chambers, so as not to expose a single rivet to the direct action of the fire.

The combustion chamber is also a welded and corrugated steel cylinder, flanged out to receive a full-sized tube sheet. These internal parts are capable of standing eleven hundred (1,100) pounds per square inch external pressure. The longitudinal seams on the outer part of the boiler are all welded, and the circular seams, the only ones riveted, are united by a double row of rivets. It will be readily understood that we can safely carry almost any pressure, and the boiler shown is designed for steam of 175 pounds per square inch.

As we have shown how it is possible to construct a boiler to meet all the requirements of a very powerful and very fast locomotive, *i. e.*, maintain a very high steam pressure at a low cost for coal and repairs—let us see how the best use can be made of that steam, and in doing this we shall again make use of well-known mechanical principles.

It is a well-recognized fact in steam engineering that the best engine is the one that gives the highest initial and lowest terminal pressures, provided she is tight and is working up to her full capacity (*i. e.*, has a full load). To do this she must have a good admission, an early cut-off, a late release, a free exhaust, and a late closure of exhaust, with enough compression to bring the pressure of the confined steam up to that of the boiler at end of stroke.

Much has been written on this question of compression, and some have asserted that it was impossible to run a locomotive at a high speed with any less compression than that given by the link motion, but they have not taken into account the question of clearances. We have found that when clearances are reduced, compression must be reduced, and that with an engine having small clearances, a very small amount of compression answers every purpose, and that more will deaden the engine.

Here was a great problem to solve, and one that has taken years of careful experiment and investigation. We are required to produce an engine with independent steam and exhaust valves, which is at the same time simple, durable and practical.

Many attempts have been made before, and many failures recorded. Careful investigation soon satisfied the writer that the flat slide or gridiron valve was the only one that would answer the purpose. Valves of this kind have stood the test for years with high pressure steam in both stationary and marine practice; but to be a success, these valves must be allowed to come almost to rest while the load is upon them; wherever previously used, some form of cam or tappet motion had been employed to actuate them. In our first experiment we tried a device of this kind, but soon found that, with the rapid motion of a locomotive, it would not do at all. We then devised the very simple arrangement of rocker shown, which is so adjusted that after a valve has travelled its lap, it comes to nearly a full stop, while the corresponding valve at the other end of the cylinder is doing its work, and as the load comes upon the valve during this period of rest, there is very little wear. As the steam of compression comes up under the valve at its period of opening, there is a still further relief, while the exhaust valve does not move until it is relieved by expansion.

The method of introducing the valves and seats is clearly shown by the drawings. The valve seats are plugs, fitting in holes bored in the passages from the saddle to the cylinder, the ordinary steam-chest being dispensed with. The valves are let into grooves milled or planed in the seats, so arranged that the valves are free to move up and down in the seats.

There are ten (10) ports in each seat on a 19 x 24 inch, or a 20 x 24 inch cylinder, each port being 4⅝ inches, giving a total port length of 46¼ inches, in each valve. This length is also, of course, that of the lead line, as against the sixteen-inch of an ordinary locomotive. This arrangement, even when the engine is making 250 revolutions per minute, gives an initial pressure within two pounds of boiler pressure, and does not allow more than five pounds drop to the point of cut-off; while the ordinary form of valve will entail a loss of fifteen pounds between boiler and initial pressures, and another fifteen during the period of admission, making a loss of thirty pounds between boiler pressure and that at the point of cut-off; while under similar circumstances, we do not by any chance lose ten pounds. We cut off at four inches, and hold on to the steam until the last inch of piston travel, thus getting six expansions. The exhaust does not close until three and one-half inches from the end of the return-stroke, avoiding excessive compression. An ordinary locomotive loses thirty-three per cent. of the mean effective pressure from compression, which necessitates a late cut-off and not more than three expansions, in order to maintain the same mean effective pressure that we get with six expansions. Now it will be readily seen why the link-motion is not good for very fast and heavy work. It can neither get the steam in nor out properly. In losing at both ends, it exhausts at too high a pressure, and does not allow an initial pressure at all near that of the boiler. All these objections are entirely overcome by the valve-gear shown, which is of the radial type.

The motion for all the valves on one side of the engine is obtained from a single eccentric, one motion of the lever attached to the eccentric moving the valves, the amount of their lap and lead, and another motion produces the opening in addition to the lead. There are two levers worked from the same eccentric strap; one being bolted rigidly to it, while the other has a pin forged on

the end of it. This pin has a bearing in a bushed hole in the strap itself, at a certain distance from their ends. Both these levers have a fulcrum pin, connected with one end of a link, whose other end is hung by means of a pin from a block, capable of being moved along a sector or arc. The path of the pin when moved along this arc is radial to the fulcrum pin already mentioned. Thus the position of this block on its sector, which is regulated through the medium of a reach rod, by the lever in the cab, determines the inclination of the travel of the fulcrum pin. When the block stands in the centre of the sector, as shown on the drawing, there is no inclination to the travel of the pin, and the valve is moved only the amount of lap and lead. If, however, the block is moved forward on the sector, the fulcrum pin travels over an inclined path, which incline represents the opening of the valve in addition to the lead, and the engine moves forward, and if the block is moved forward to the end of the sector, the full travel of the valve is given, and steam follows the piston twenty inches of its twenty-four-inch stroke; if, on the other hand, the block is moved back past the centre, the path of the fulcrum pin is reversed, and the engine will run backwards. Thus it will be clearly seen, that by varying the position of the block on the sector, the travel of the valve is varied as well as the point of cut-off, which latter may be anywhere between four inches and twenty inches. In all cases the exhaust valve is allowed to travel its full stroke, and as it is worked by the lever having the pin forged on its end, and from a separate fulcrum pin, with an independent link, block and sector, its travel may be varied at will, and so, of course, may the steam valve. In ordinary working, however, the exhaust block is never moved on its sector, except for reversing, when both steam and exhaust-blocks are moved at the same time; after the engine is started, the steam valves are hooked up, but the exhaust is not disturbed. The steam valves are given one-eighth inch lead and the exhaust five-sixteenths inch.

(SECOND PAPER.)*

As the result of the trials of the Strong engine on the Lehigh Valley road, made in April and May, 1887, to develop the strong and the weak points of the engine, certain small alterations in detail have been introduced, which will considerably improve the engine as originally designed.

Of these alterations, one is the change in the method of riveting the seams in the furnaces. None of these are now made with the lap-joint, but instead, the Adamson flanged seam is employed. This is made by flanging outwards the cylinders forming the furnaces, combustion chamber and junction pieces, at right angles to the plate, and connecting the pieces thus flanged by rivets passing through each flange and an intermediate ring about five-eighths inch thick. This joint, therefore, exposes no rivet to the action of the fire, and nowhere is there a greater than a single thickness of plate between fire and water. Tightness and freedom from burning are thus secured, as well as strength and stiffness against collapse, for which the Adamson joint is so suited that it is almost universally employed in the great steam-using centre, Lancashire, England, as the furnace seam of Lancashire boilers which carry safely 100 pounds of steam, outside furnaces of three feet diameter, the joint occurring at every two feet, or 2 feet 6 inches. Another alteration in the boiler, is the welding of all the longitudinal seams. This operation, hitherto looked upon as uncertain, has been rendered completely safe by the introduction, into modern practice, of gas for all the operations of the forge and rolling mill. By suitable application of gas, surfaces to be welded may be heated to a proper temperature, and kept clean and free from dirt and scale. By this, there is a certainty in the welding operation hitherto unattainable, and sound welding, having the full strength of solid plate, may now be regularly effected. By this means, a boiler may be constructed in which all the waste of rivet heads and overlaps is avoided.

Further than this, as a riveted seam never has above eighty per cent. of solid plate strength, we effect a very large saving by welding, in the possible twenty per cent. reduction of plate thickness,

* Read at the Stated Meeting of the INSTITUTE, Wednesday, Dec. 21, 1887. Being a Summary of the Results of Trials of the Engine on the Lehigh Valley Railroad, made by Mr. E. D. Leavitt; with comments thereon.

or, if we adhere to the same plate thickness, our boiler is twenty-five per cent. stronger than when riveted. By employing the Adamson seam also for the last seam to be riveted of the boiler shell, we are able to say that we have a boiler, every rivet of which may be closed by power, no hand work being required for any rivet of the outer shell. By a suitable design of the various connecting pieces of the furnace parts and outer shell, we shall in all future construction press these parts, which are of irregular form, from single plates instead as we are now doing from four parts, and by so doing will do away with any riveting or welding on these parts, as well as to save a large amount of stock, which is now waste in fitting these parts.

In present designs, there is a greater steam space over the furnaces than in the experimental engine, and the diameter of the boiler barrel has been increased to sixty inches, so affording larger steam space. Means also have been taken to utilize a portion of the waste heat of the exhaust steam to heat up the feed water, branch pipes being taken from the exhaust passages in the cylinder saddles and a portion of the exhaust steam led through a species of injector to combine with the feed supply to the boiler pump. The trials of the experimental engine have demonstrated the fact that, as a material for valves, cast iron is superior to steel, a set of steel valves tried for experiment having proved inferior to cast iron.

Since the reading of a paper on the Strong Locomotive before this INSTITUTE, in February, 1887, extended tests have been made on the Lehigh Valley Railroad, by Mr. E. D. Leavitt, of two locomotives fitted with the Strong valve gear, and of one ordinary locomotive. These engines were Nos. 357, 383 and 444. No. 357 was of the ordinary type; No. 383 had the Strong valve gear; No. 444 had both the Strong gear and the Strong boiler.

Engine No. 383 has an ordinary straight-top boiler, with fire box over instead of between the frames, and anthracite coal grates. Engine No. 357 has an ordinary boiler, similar to that on engine No. 383, but with a "wagon top" of eight inches, and the link motion, with plain slide valves having DeLancey's balancing device.

Annexed are the leading particulars of the three locomotives.

It will not here be necessary to detail the manner in which the tests were made. It is sufficient to remark that coal weights and water measurements were made with all the care and accuracy

customary in engine tests, and indicator diagrams were carefully taken with the Tabor indicator, and proper notes made of steam pressure and speeds, so as to insure the accuracy of the results obtained. In estimating the amount of steam consumed per indicated horse-power, as shown by the diagrams, the gross amount was first computed from the pressure in the cylinder, just before the opening of the exhaust valve. From this was subtracted the amount of steam remaining in the cylinder when the exhaust port closed. In each case, the volume of the clearances was taken into the calculation, and the result shows the net amount of steam consumed. To this, of course, it is necessary to add a certain percentage for cylinder condensation, in order to arrive at an approximately correct estimate of the water consumption per horse-power, which, of course, cannot be obtained from direct measurement of the cards. As, however, the percentage to be added cannot, in any case, vary appreciably in any of the engines from the same amount, we may take the card measurements of dry steam as representing pretty accurately the relative consumption of the various engines. Comparing on this basis No. 383 and No. 357, we find that an average of six cards from No. 383 show a consumption of 22·34 pounds per horse-power, and that a similar average from engine No. 357 shows 26·73 from five cards. The horse-power shown by these cards is for No. 383, 540·8, and for No. 357 is 380·2, the larger power showing considerably less water consumption. An examination of the cards shows that the link motion of engine 357, though of the best design, has the fault common to all link gears, namely, over-compression. From this the Strong gear is free, and the compression line in the cards of No. 383 show a marked difference from those of No. 357, especially, of course, at the earlier grades of cut-off. This reduction in compression greatly increases the area of the cards, and may have several results. First, it admits of earlier cut-off, and so saves steam for equal power developed. Secondly, for same point of cut-off it increases the mean effective pressure, and therewith the tractive power of the engine, so allowing of a heavier train at same speed, or of a higher speed. Generally it increases the efficiency of the engine as a motive-power, it enlarges the range of power, and increases the tractive force at high speeds per ton of weight.

It is true that by compressing the residual steam in a cylinder, we may render an engine more economical, but to this economical compression there is a limit, especially in locomotives. In a stationary engine, specially designed for certain work, we may fix our compression and proportion our cylinder accordingly, but in a locomotive which is required to work with fair economy through a very wide range of power, the conditions are very different, and in any case the great amount of compression given by the link motion at the earlier grades is unnecessary and harmful.

The cards from No. 383 show quite enough rounding of the lower corner of the diagram and compare most favorably with those from No. 357. It is equally noticeable that the cards from No. 383 show a much closer approach of the initial steam line to the boiler pressure than do those of No. 357, and the steam line is better maintained up to the point of cut-off, thus proving the great superiority of the Strong gear all round. This higher initial pressure is due to the great length of port opening given by the multi-ported or grid-iron form of valve, and the more defined cut-off is due to the peculiar arrangement of the rockers which actuate the valves and give a very rapid opening and closing of the ports. The final result is a card of large area and therefore a high mean effective pressure, which cannot be obtained with over-compression, and it is plainly visible from the cards 7 and 11, how, with a much earlier cut-off, a very much greater power is developed from No. 383 than from No. 357. All the cards shown were taken on up grades; the maximum being ninety-six feet per mile, between Sugar Notch and Fairview going south, and sixty-nine feet per mile going north between White Haven and Glen Summit. Though usual on the north trip to have a helper, none was allowed during the tests, so that the performance of each engine was accurately gauged. Each engine was made to run its best between the two points, hence the time spent by each upon this run may be taken as a good index of its capacity.

Taking the two fastest runs of Nos. 383 and 357 between Sugar Notch and Fairview, namely those on the 9th and 10th of May, the mean initial pressure of nineteen sets of diagrams is as follows:

No. 383, May 10th, mean boiler pressure, 159 pounds; No. 357, May 9th, mean boiler pressure, 151 pounds. These figures multiplied

by the tractive force per pound give for No. 383, $159 \times 131{\cdot}3 = 20877$, and for No. 357, $151 \times 149{\cdot}1 = 22514$, as the relative powers of the two locomotives. In other words, No. 357 should be 7·8 per cent. better than No. 383. Actually, however, No. 357 was 9·4 per cent. slower than No. 383. From this we can only draw the inference that the superior valve gear of 383 was nearly twenty per cent. more efficient than the link gear of 357. With boilers so nearly similar, the tests showed that the water consumption of 383 was 20·3 per cent. less than that of 357, and as the train loads were the same for each engine, it is clear that the superior form of the diagram from the Strong gear is to be credited with the difference.

The tests further developed the fact that No. 444 consumed very much less coal than either of the other engines, and this clearly indicates the superiority of the Strong boiler. The engineer of No. 444 kept the throttle partially closed, being generally rather nervous and unacquainted with the engine, and hence the water consumption was greater than it should have been. Notwithstanding this drawback, the work was done with 23·7 per cent. less coal than used by No. 357, and 8·7 per cent. less than that used by No. 383. Now, the cards from No. 383 are superior to those of No. 444, owing to the foregoing facts, and further to the fact that the blast nozzle of No. 444 was much too small and caused a heavy back pressure. It may then be fairly reasoned that, though No. 444 consumed more water than No. 383, she used less coal as a result of the new type of boiler.

In engines now constructing, we shall obtain cards fully equal or even superior to those of No. 383, and a boiler which will show an efficiency far superior to that of the ordinary type.

There is no reason whatever why the Strong boiler should be expensive to construct, for in place of the multitude of screwed stays and the riveted rectangular box with massive roof-bar stays, we substitute machine-made furnaces and combustion chamber, and abolish at a stroke all fire-box stays with their attendant labor and cost of repairs and maintenance. Our boiler has in fact the fewest possible number of parts, all formed by machinery and power riveted. Such a structure cannot but be stronger and cheaper than the old type of boiler which has such large surfaces exposed to transverse stress, for which thin plates are so unsuited, and hence

require the aid of screwed stays to resist by tension the steam pressure, which cannot possibly be carried by flat, unsupported plates.

The modern necessity for high pressures calls for some different form to resist such pressures than the rectangular stayed box, which contains within itself the elements of destruction, from the unequal expansion of parts heated to different degrees of temperature.

With acquired experience and in the light of modern methods of work and with modern materials and tools, it is time to depart from methods and types which were the best possible thirty years ago, when the locomotive was not developed to its present state of efficiency.

This thirty-years'-old practice we have been following until to-day. Without in any way reflecting upon the qualities of a machine which met the requirements of a generation back, in respect to speed and cheapness, it may be said that the time has arrived to make a fresh deparature to meet present-day demands. We have now at our command the newer material, steel, which, whether forged or cast, is better than wrought iron for boilers, wheels, and moving parts generally. By the use of powerful hydraulic presses, steel plates of large size may be pressed into almost any form, and thus we can construct boilers well and cheaply, and containing few parts, few rivets or stays.

We have carefully worked out our locomotive and determined upon our standards for different classes of work, designing these standards so as to employ the greatest number of interchangeable parts, and each class is specially designed for its work with such proportion of parts and ratios of expansion, wheel diameter, piston speeds, etc., as experience and investigation have shown us to be suitable and economical. With these proportions once determined, and a sufficient number of standard types settled, it is a simple matter to manufacture locomotives of any class cheaply and well by the modern method of work. To-day, more than ever, are special tools employed in special work, machines designed for accurately and rapidly finishing any detail which, as it comes from the tool, is ready for the erector.

To follow out this system with our locomotive, we should employ a special machine for boring and facing up the cylinders, which,

with two settings, would not only do this, but also mill the frame recesses and bore out the valve-seat chambers, and generally leave the cylinder complete for its position in the locomotive. In a similar manner, at one setting, we may finish the frames, and generally, by a free use of the milling tool, drop press and steel castings, cheapen the cost of production very considerably. Indeed, the improvements in the manufacture of steel, both cast and wrought, have opened up a very wide field to the machinist and rendered possible methods of work hitherto out of reach.

The revolution in marine practice, effected by the introduction of the corrugated furnace, has not been greater than it will effect in locomotive practice, where the use of high pressure first commenced. Formerly very far behind, marine boiler pressure is now ahead of locomotive practice, which has remained practically stationary, but there is no reason why an advance should not now be made.

It has been shown by the tests made, that a horse-power may be obtained from 21·33 pounds of dry steam, and an evaporation of 8·56 pounds of water per pound of coal has been also shown from a feed temperature of only 64° to a pressure of 170. By means of the arrangement for heating the feed by a portion of the exhaust steam, an evaporation of 9·84 pounds from feed at 212° should be secured. Now with an evaporation of 9·84 and a pressure of 175 dry steam and as we have shown that a horse-power can be had for 21·33 pounds of dry steam or water evaporated into dry steam, which was found by actual measurement of the water used and not calculated from the card, we may safely count on a horse-power from 21·33 = 9·84 — 2·16 pounds of good coal per hour, as it has been shown by these tests that the re-evaporation takes up all the losses from cylinder condensation as accounted for by the card, and our water by measurement and by the card do not differ.

No. 444, when run on the Northern Pacific Railroad by an engineer who kept a fairly open throttle, developed at high speed over 1,800 horse-power, or over one horse-power from a square foot of heating surface, or thirty horse-power per foot of grate and a horse-power per every seventy-five pounds weight. She has boiler-power sufficient to hold out at this high speed indefinitely, and could do the same with a heavier train with a larger blast nozzle. No. 357 could probably not show higher than 764 horse-

LEADING PARTICULARS OF LEHIGH VALLEY LOCOMOTIVES, NOS. 357, 383 AND 444.

	ENGINE 444.	ENGINE 383.	ENGINE 357
CYLINDERS, ETC.—			
Cylinder, diameter and stroke,	20 ins. by 24 ins.,	19 in. by 24 in.,	20¼ by 24 ins.
Diameter of piston rod,	3¼ ins.,	3¼ ins.,	2⅞ and 2¾ ins.
Length of connecting rod, centres,	8 ft. 3 in.,		
Transverse distance between cylinder, centres,	7 ft.,		
Distance from centre of main drivers to centres of cylinders,	12 ft. 10 ins.,		
Number of valves per cylinder,	4, 2 steam, 2 exh.,	4, 2 steam, 2 exh.,	One.
Type of valves,	Gridiron,	Gridiron,	Balanced slide.
Number of ports per valve,	10,	10,	
Size of ports,	4⅝ ins. by ¾ in.,		
Full travel of valves,	1 1/16 in.,	1 1/16 in.,	
Lap of valves,	5/16 in.,		
Lead of valves, steam,	⅛ in. constant,	⅛ in. constant,	
Lead of valves, exhaust,	5/16 in. constant,	5/16 in. constant,	
Throw of eccentrics,	2½ ins.,		
Tractive force per pound of mean effective pressure on piston,	154·8 pounds,	131·3 pounds,	149·11 pounds.
Cylinder clearance in cubic inches,	481,	448,	568.
Cylinder clearance in per cent. of piston displacement,	6·38 per cent.,	6·58 per cent.,	7·35 per cent.
WHEELS AND JOURNALS.—			
Driving and truck wheel centres (all tires of steel),	Wrought iron,	Cast iron,	Cast iron.
Front truck 4-wheeled swing beam,	Yes,	Yes,	Yes.
Rear truck 2-wheeled swing and radius bar,	Yes,	None,	None.
Nominal diameter of driving wheels,	62 ins.,	66 ins.,	68 ins.
Calipered diameter of driving wheels,	62 ⅛ ins.,	65 1/16 ins.,	66¼ ins.
Diameter of front truck wheels,	30 ins.,		
Diameter of rear truck wheels,	42 ins.,		
Total wheel-base of engine,	30 ft. 2 ins.,	22 ft. 9 ins.,	22 ft. 1 in.
Rigid wheel-base of engine,	5 ft. 7 ins.,	7 ft. 9 ins.,	7 ft.
Driving axle journals (diameter and length),	7½ ins. by 10 ins.,		
Front truck axle journals (diameter and length),	6 ins by 11 ins.,		
Rear truck axle journals (diameter and length),	7 ins. by 9 ins.,		
Main crank pin journals (diameter and length),	5 ins. by 6 ins,		
Coupling rod journals (diameter and length),	4¼ ins. by 4 ins.,		
WEIGHTS, ETC.—			
Weight on first pair drivers, in working order,	30,000 pounds,		
Weight on second pair drivers, in working order,	30,000 pounds,		
Weight on third pair drivers, in working order,	30,000 pounds,	None,	None.
Total on drivers, in working order,	90,000 pounds,	74,640 pounds,	63,280 pounds.
Weight on front truck, in working order,	27,000 pounds,	24,880 pounds,	27,440 pounds.
Weight on rear truck, in working order,	21,000 pounds,	None,	None.
Total weight of engine, in working order,	138,000 pounds,	99,520 pounds,	90,720 pounds.
BOILERS, ETC.—			
Heighth of boiler centre above rail,	7 ft. 3 ins.,		
Kind of boiler,	Twin Furnace,	Straight shell,	Wagon top.
Material for boiler plate,	O. H. Steel,	O. H. Steel,	O. H. steel.
Diameter of barrel inside smallest ring,	58 ins.,	55 ins,	54 ins.
Diameter of fire boxes and combustion chambers, corrugated,	38¼ ins. inside, 42⅝ ins. outside,		
Length of grates,	9 ft. 0 ins.,	11 ft,	11 ft.
Width of grates,	3 ft. 4 in,	3 ft. 4½ ins.,	3 ft. 6¼ ins.
Number of tubes, all iron,	306,	229,	248.
Diameter of tubes, outside,	1¾ ins.,	2 ins.,	2 ins.
Length of tubes,	11 ft. 5 ins,	11 ft 4½ ins.,	12 ft. 2 ins.
Grate area, square feet,	62 sq. ft.,	37 12 sq. ft.,	39 2 sq. ft.
Heating surface, fire box, square feet,	155,	151 6,	142·3.
Heating surface, combustion chamber, square feet,	93,		
Heating surface, tubes, square feet,	1600,	1234·3,	1429·8.
Heating surface, total, square feet,	1848,	1385·9,	1572·1.
Ratio of heating surface to grate area,	29 8 to 1,	37·3 to 1,	40·1 to 1.
Smallest inside diameter of smoke stack,	16 ins.,		
Height of top of smoke stack above rail,	14 ft. 3 ins.,		
Working steam pressure per square inch,	160 lbs.,	160 lbs.,	140 lbs.
TENDER.—			
Eight-wheeled double trucks—Diameter of wheels,	33 ins.,		
Capacity of tender (gallons),	3,000,		
Capacity of tender (coal),	10,000 lbs.,		
Weight of tender loaded, (Same tender used on all tests.)	70,000 lbs.,		

power, which would make her weight per horse-power 118 pounds, and show only nineteen horse-power per foot of grate. No. 444, therefore, though with a large grate, shows a still larger power per foot of grate, which proves that the principle of the boiler with the extended combustion chamber is good. No. 383 also, though heavier per foot of grate than 357, owing to heavier general build, developed a horse-power for each 112 pounds weight and twenty-three horse-power per foot of grate surface, and this plainly shows the superiority of the Strong valve gear.

The complication of balanced valves and the difficulty in keeping them in order and tight has prevented their introduction, and we recently heard of a case where the steam consumption of the balanced valve was ten per cent. above that of unbalanced valve engines. With the Strong quadruple valves, all the advantages of balancing are secured without its complications, for, by the peculiarity of the motion given by the rocker gear, it is so secured that when the load on the valves is greatest, they are mostly at rest, and when they are moving, the compression coming beneath the steam valves so relieves them of load that they are to a large extent balanced, whilst similarly when the turn comes for the exhaust valves to move, they are exposed only to the pressure from the expanded steam. The fact that in actual work the wear of the valves is found to be almost *nil*, confirms these views and shows that the grid-iron form of valve, long successfully employed in stationary practice, has been wisely chosen, and that the use of four separate valves, each moving when needed, is better than one large valve, which is constantly on the move and with which a proper steam distribution is impossible. The question of balancing has thus been very satisfactorily settled.

The engravings herewith show clearly the various details of the boiler and valve gear, and the form of the indicator cards obtained from the different engines tested

THE SOUTHERN ANTHRACITE COAL FIELD OF PENNSYLVANIA—ITS ENORMOUS DISTURBANCES AND CONSEQUENT PREMATURE EXHAUSTION.

BY HENRY A. WASMUTH.

The southern anthracite coal field forms a long, narrow synclinal (with occasional projecting fingers), extending from Carbon County to Dauphin County for a length of about sixty-five miles. The greatest width of the basin, a combination of minor rolls, is in the neighborhood of Pottsville—Minersville.

Messrs. Sheafer, E.M., at Pottsville, state the area of this coal field to be 93,440 acres, carrying a total thickness of coal of 102 feet, deposited in beds from three to twenty-five feet thick. The workable coal is estimated at twenty-five yards, of which probably two-thirds will go to waste and one-third will be marketed, the probable yield being 3,768,746,666 tons.

The fact that the strata of the southern coal field are distorted and dislocated by numerous longitudinal and transverse faults of more or less extent, has been established more than forty years. Where such faults have been intersected by cross cuts, no importance whatever has been given to them, because those in charge were unacquainted with the appearance of dislocating faults, and where longitudinal faults have been met with in the anthracite beds they have termed them "inversions."

The existence of "inversions" in coal beds has not been established in any part of the globe, for, whatever the condition of the measures and coal beds might have been—plastic or hard—at the time of their disturbance from the original horizontal position, their folding into shapes, as constructed by the mining engineers and geologists of the anthracite region, must have been accompanied by compressing the whole strata into a smaller space, which could not take place without more or less fracturing and dislocation of the strata. Geologist Rogers defined the character of longitudinal and transverse faults more than thirty years ago in accordance with the definitions of all authorities in Europe, and the imported notion

that the term "inversion" covers all information concerning longitudinal faulting, is based on total ignorance of stratification, and such notions must and have been disastrous to anthracite mining ever since; for the knowledge of the geometrical position of the mostly steep inclined anthracite beds is indispensable for laying out proper working plans.

In order to prove the existence of great disturbances of the anthracite measures, I will cite a number of occurrences.

The Williamstown Colliery, Dauphin County, controlled by the Pennsylvania Railroad Company, has been opened by a tunnel from the northern slope of Wiconisco Valley to Bear Valley (through Big Lick Mountain). The southern tunnel mouth is located in red shale with gentle north-dipping measures. About 400 feet north of the tunnel mouth a fault with south dip (contrary dip) is visible; its width is about ten feet, and it is filled with large pebbles and clay. The effects of this fault are similar to those of transverse faults.

The tunnel has intersected the series of the Lykens Valley coal beds; the main Lykens in an exceedingly fine condition.

About 1,000 feet north of the main Lykens bed, a longitudinal fault has been intersected by the tunnel; its strike is nearly parallel with the strike of the measures; its width is from a few inches to three feet and more, and it is filled with disintegrated and large fragments of rock; its bottom and top rock are polished and with distinct striation, thus indicating the course of movement of the broken strata.

The southern portion of the formation, viz., the part on the footwall of the fault, has slid down on the northern portion of the formation.

From the fault referred to, to the northern tunnel mouth, a distance of about 1,500 feet, all the strata are distorted and confusedly dislocated by at least three distinct faults. One of these faults is from one to six feet wide and is filled with clay and large bowlders of conglomerate. The main Lykens bed has been worked seven levels below the tunnel on an incline of from 20° to 45° north, and according to the parallelism of the strata, the Buck Mountain coal bed should have been intersected by the tunnel within 1,300 to 1,500 feet north of the main Lykens, but it has been intersected in a disturbed condition at about 2,200 feet.

The fault referred to will be struck on the incline of the main Lykens bed not very far below the seventh level at about the elevation of the tide line.

From this brief review of the strata intersected by the tunnel, it is unquestionable that only one great dislocation of the north-dipping coal measures has taken place, accompanied by consequent crushing, fracturing, etc., increasing towards the northern synclinal axis, a phenomenon similar to the enormous disturbances of the strata in the Panther Creek region.

The disturbance of the north-dipping flexure of the Mammoth bed in East Franklin Colliery was indicated more than ten years ago, and the colliery, with an additional outfit of new improvements, had to be abandoned on account of longitudinal faulting, etc.

Similar disturbances were indicated many years ago on the south-dipping flexure of the Mammoth bed in Lower Rausch Creek Colliery, and confirmed in the lowest western gangway. This colliery has also been abandoned.

Around Middle Creek Colliery there are indicated great disturbances of the strata, for east of Middle Creek (opposite the big rock) several adits have been extended towards the east on gentle north and south-dipping flexures of the Buck Mountain coal bed. Within a short distance south of these adits, the Buck Mountain bed crops out more than 150 feet above those adit levels, showing an incline of about 40° south. Is it imaginable that such sudden changes in the inclination of the strata within a comparatively short distance could have originated without disconnection and dislocation? and this phenomenon must have its origin in dislocation of the strata either by a longitudinal fault, or by a transverse fault with contrary dip.

The existence of another more southerly longitudinal fault is indicated by two old slopes in an almost vertical plane on the Mammoth bed and confirmed in the lower workings from the shaft. Of course, the phenomenon has been termed an inversion ever since.

The great dislocation of the whole carboniferous formation by a longitudinal fault in Otto Colliery was struck about forty years ago, but the phenomenon has been an enigma to geologists and the officers in charge ever since, and thus all of the improvements of the old White Ash slope have been entirely wasted.

The topography of Panther Creek region is favorable to mining above water level, and the strata of both flexures of the narrow synclinal have been crossed by numerous adits. The *Second Geological Survey of Pennsylvania* has constructed this basin as a combination of several synclinals and anticlinals, but an investigation of only one cross-cut or adit on each flexure of the synclinal will be convincing that the strata of both flexures is enormously distorted by crushing, disconnection and dislocation by faults of both characters, and that there is no room for even a conception of the existence of the rolls constructed by the Survey.

The coal measures west of Tamaqua have not been crossed in their whole width so thoroughly as in Panther Creek, but from the enormously exposed disturbances in the latter region, from the numerous great distortions of the strata from Williamstown to Branchdale, and from the uniform general conditions of the whole basin, it must be concluded that similar disturbances of the strata exist from Tamaqua to Branchdale.

I venture to say, that in consequence of those great oblique dislocations by longitudinal faults, etc , the amount of workable coal is comparatively small below the elevation of the tide line in the southern field, which could be established pretty closely by sections through points where the longitudinal faults have been struck in the lowest gangways; for instance, Lower Rausch Creek, East Franklin, Middle Creek, Otto Collieries, etc., and such sections would also prove that the failure of Pottsville shaft with its long cross-cut is due only to lack of knowledge of stratification.

Furthermore, the marketable coal of the contents of the Mammoth bed in fair condition is estimated to be about thirty per cent., and it is therefore indubitable that the shipments of the contents of the distorted flexures of the bed, forming the main basin, and the flexure in Sharp Mountain hardly will exceed fifteen per cent. Of course, the flexures of the lower and upperlying beds will give additional shipments of uncertain amounts. But it is stated by the *Second Geological Survey*, that heretofore principally coal beds of six feet and more in thickness have been worked, and if the exhaustion of the finest coal beds on the globe has not been satisfactory to investors, as the expenses of mining towards the depth increase in geometrical progression, the question is at hand:

(1.) Is it possible that, by lack of knowledge of stratification the mine maps could represent the condition of the strata?

(2.) Could any estimate of the contents of coal beds, based on incomplete mine maps, be reliable? and must not those estimates referred to be greatly exaggerated?

(3.) In the face of the almost inexhaustible supply of cheap bituminous coal in Western Pennsylvania, is there any prospect of mining profitably at present prices the dislocated rolls of the series of coal beds forming the main synclinal?

I say, no, and feel assured that an investigation of the matter, by competent experts, which will of necessity be inexpensive, will thoroughly prove the truth of my statement, and at the same time convince those who are interested in anthracite mining in the southern coal field.

4128 Elm Avenue, Philadelphia, December, 1887.

STEAM BOILER TEST WITH DOWNWARD-DRAUGHT FURNACE.

By Francis E. Galloupe, M.E.

As a supplement to the investigation of Messrs. Lozano and Erben upon downward-draught furnaces, in recent issues of the JOURNAL*, the appended report of a trial since made by the writer, in Boston, may not be without interest.

While it is not the writer's wish to criticise the investigation alluded to in detail, and while work of undoubted value has been done there in the analysis of the coal and furnace gases, some points necessary to the carrying out of the details of the tests in a proper manner seem to have been overlooked.

The first point to which attention may be drawn is the large percentage of refuse from the coal in the furnace at the end of the trials, amounting to twenty-seven per cent. in weight of the total coal burned in the first trial (ordinary furnace), and nearly twenty-seven per cent. with the downward-draught furnance. Deducting from the total coal burned (4,652 pounds) so large a quantity as 713 pounds as unburned coal, when this must have parted with

* JOURNAL OF THE FRANKLIN INSTITUTE for November and December, 1887.

some of its calorific power if put into the furnace at all, and deducting from the total (3,692 pounds) in the second trial, 417 pounds as unburned coal, gives percentages of unburned coal to total coal of 15·5 in the first and about 11·25 per cent. in the second trial. This would indicate of itself, by the smaller percentage, that the downward-draught furnace burned the coal up cleaner than the ordinary furnace, or else that less loss resulted with the downward-draught furnace from coal dropping through the grate, showing the water-tube grate to have been superior to the ordinary grate in this respect.

The second point which may be made is in regard to the water level. This varied from one inch height to four inches in the first trial, and from 1·5 to 4·5 in the second. For best evaporative work it should be kept as nearly constant as possible during the test; these variations may have been unavoidable, but are certainly not desirable. The admission that the water level was left one-half inch higher at the end of the second test "through inadvertency" makes the feed water record inaccurate, and no attempt appears to have been made to correct it for this difference of level, which might amount to 180 or more pounds of water. In ending a test, the water level in boiler should be brought to exactly the same height as at the beginning, and the steam pressure as near the same as may be possible in burning out all the coal in the furnace after the final charge.

It will be seen that in the following results a close agreement exists in some of them, while a considerable variation occurs in others; for instance, the percentages of ashes in the three trials are respectively, 14·1, 17·6 and 18·69 (refuse); the actual evaporation per pound of dry coal, 9·13, 8·47 and 8·42; equivalent from and at 212°, 9·61, 8·81 and 9·37; equivalent per pound of combustible, 11·19, 10·70 and 11·53, but the results are given without further comment.

TRIAL OF A TWENTY-FIVE HORSE-POWER VERTICAL TUBE STEAM BOILER, WITH DOWNWARD-DRAUGHT FURNACE.

Place and date of trial, East Somerville, Mass., December 14, 1887.

Duration of trial, ... 10 hours.
Weather, clear; barometer, 30·27; thermometer, 37, average; wind, light; direction, Southeast, velocity, 5 miles per hour.

DIMENSIONS AND PROPORTIONS.

Boiler, with box furnace, height,	6 feet.
Depth, inside, front to rear,	5 "
Tubes, 2 inches outside diameter, number 89, length,	5 "
Furnace, width, 3 feet 6 inches; length, 3 feet.	
Grate, 1-inch tubes; number, 21; length, 2 feet 6 inches; entering gun metal box at front, 6 inches wide; grate inclined 1 inch to 1 foot; underneath connecting pipes, 2 inches diameter; number, 6; inclined 2 inches to 1 foot.	
Air space through grate,	2·87 square feet.
Grate area, 3 feet 6 inches wide by 2 feet 6 inches long,	8·75 " "
Area in undertake to tubes,	3·50 " "
Area through tubes,	1·85 " "
Uptake to chimney, 16 inches diameter; length, 2 feet; area,	1·40 " "
Chimney, brick; size, 16 inches by 20 inches; area,	2·22 " "
Chimney, height above grate,	35 feet.
Heating surface in furnace,	70 square feet.
Heating surface in grate,	30 " "
Heating surface in tubes,	233 " "
Total heating surface,	333 " "
Square feet heating surface per square foot grate,	38 " "

RESULTS.

Steam pressure, by gauge, average,	60·5 pounds.
Temperatures, boiler room, "	67·5° F.
" outside air, "	41° "
" feed water, "	43·3 "
" water entering boiler, average,	132·5 "
Fuel, weight kindling wood, 46 pounds (= @ ·4, 19 pounds coal).	
Total coal,	1,070 pounds.
" equivalent dry Cumberland coal consumed,	1,089 "
" refuse, 200 pounds; percentage of net coal,	18·69 "
Total combustible consumed,	889 "
Dry coal consumed per hour,	107 "
" " " " square foot grate per hour,	10·22 "
Water, weighed, 9,273 pounds; corrected weight actually fed and evaporated,	9,169 "
Economic Evaporation. Water per pound dry coal from actual pressure and temperature feed,	8·42 "
Equivalent evaporation per pound dry coal from and at 212° F.,	9·37 "

Equivalent evaporation per pound combustible,	11·53	pounds.
Commercial Evaporation. Equivalent water evaporated per pound dry coal with one-sixth refuse, at seventy pounds gauge pressure, from 100° temperature,	8·36	"
Rate of Evaporation. Water, from and at 212° F. per square foot heating surface her hour,	3·06	"
Commercial Horse-power. At thirty pounds water per hour, evaporated from 100° F. into steam, at seventy pounds gauge pressure,	29·57	
Horse-power, builders rating (sixty pounds steam pressure),	25·	
Horse-power, per cent. developed above rating,	18·28	

It may be added that no attempt was made to obtain higher results than would be had in regular running, under ordinary working conditions, with good bituminous coal and good firing.

The results show a good evaporative performance, the equivalent, 11·53 pounds of steam obtained for each pound of combustible burned from and at 212° F. being something over one-half pound more than the average result of the Centennial tests, which was 10·99 pounds. The proportions of parts were not all that could be desired; for instance, the uptake to chimney should not be of less cross-sectional area than that through the tubes. The chimney was not high enough to produce the best results. This is shown by the large percentage of refuse. With sufficient draught it would be possible to reduce this percentage from thirty-three to fifty per cent., and this saving would probably show in an increased evaporation per pound of coal. The damper in uptake was kept wide open throughout the test, and there was but little smoke.

The steam appeared to be of excellent quality and practically dry, and there was no priming. Most of the coal used was in lumps and contained too little moisture to be ascertained by weighing, after a quantity of it had been dried for nine hours. The water consumption was accurately obtained, and there were no leakages. The water level in the boiler was the same at the beginning and end of test, and the steam pressure within five pounds of the average pressure at both those points.

Boston, December 29, 1887.

The LIMITING NUMBERS of GEAR TEETH.*

By George B. Grant, Boston.

In the study of Kinematics, or the Theory of Pure Mechanism, there is no one subject that is as extensive and as intimately connected with mathematics, and few as interesting and important, as the theory of gear wheels. It is a favorite study with mathematicians, and has been extended and developed to a degree that is perhaps beyond its real importance in some directions.

In the theory of gear wheels there is no one item that is more difficult to handle, or that has been more befogged and complicated by the efforts of learned writers, than that of the limiting numbers of gear teeth.

Prof. Willis, perceiving the difficulty of a definite mathematical treatment, contented himself with a mechanical solution which can give but a rough approximation at best, and which is useless in extreme cases or for ordinary use and study.

Prof. MacCord, with commendable energy, has carried the work much further, and by a mathematical process has found and tabulated results that are generally reliable, although not as much so as claimed, but his methods are complicated and bewildering in the extreme, and require the most patient and laborious attention either to understand or apply. His results must be taken on his great reputation as a computer, unless the student has an abundance of time and energy to devote to their verification.

The bevel gear is not treated by either Willis or MacCord, and indeed it would require unusual courage to attack it by either of the methods they give. The recent introduction of machines for planing bevel gears with theoretically perfect teeth, gives to this enquiry a new importance, and necessitates a new and more available process.

---

* In the *Scientific American Supplement* for May 7, 1887, I published an article on this subject; but I had not at that time applied the process to bevel gears or to internal gears. That paper will bear correction and improvement in several particulars. It contains matter, not in this article, relating to the non-interchangeable involute tooth, and to unreversible gears.

Neither author treats of the internal involute gear.

The following method is capable of being applied to particular cases with but little labor, as it requires nothing more than the substitution of the known data in the given formulæ. As the formulæ are all founded on the simplest rules of trigonometry, I will not take space to detail the processes by which they are obtained, but will simply explain them and give a few examples.

THE GENERAL PROBLEM.

When the number of teeth in a gear is small, it may leave contact with the mating gear before a required arc of recess has been taken up, and the problem is to find the numbers of teeth that will just take up the given recess.

In *Fig. 1*, which is drawn on the surface of a sphere, so that the gears are bevel gears, we have two gears, of diameters d and f, running together on centres D and F. The driver D, runs in the direction of the arrow, and drives the follower F.

The point of contact between the two teeth must travel along a certain line, $X'\ V'\ O\ H\ V\ X$, which is called the "line of action." The line of action for the approach need bear no resemblance to that for the recess unless the gears are to belong to an interchangeable set, and hence it is seen that the two actions have no neces-

sary connection, and that whatever may occur on one is independent of the conditions on the other. If the gears are to be interchangeable, both actions may have to be considered, but not otherwise, and for the present we will consider the recess alone.

In any limiting case, when a certain arc of recess OR, has been taken up, the point of the tooth must be on the line of action at H, and the direct object in view is to so determine the line of action that it shall meet the condition. When the line has been determined, the minimum number of teeth in the follower is determined by it by conditions that differ in each case.

To simplify the work, we will set the diametral pitch at unity, so that the circular pitch is π; we will assume the arc of recess to be a certain part of the pitch, as $a\,\pi$, and we will assume the thickness of the tooth, $2\,TR$, as $b\,\pi$.

The solution of the problem lies in the simple solution of a spherical triangle, for if we can determine the forms of four of the six parts of such a triangle, we can form an equation between them which will determine either part that is chosen as the variable.

In all cases we have

$$sine\ O\ D = \beta = \frac{d}{2\ R} \tag{1}$$

and also the limiting angle

$$O\ D\ H = W = \frac{360}{d}\left(a - \frac{b}{2}\right) \tag{2}$$

but we can go no further without first fixing the form of the line of action and determining the system to which the gears belong.

In general, a gear will drive any gear down to a certain limit that is fixed by the given formula. It will drive any internal gear not greater than the limit with which it will not interfere. It will not drive a gear that is under the limit, but it can generally be driven by it.

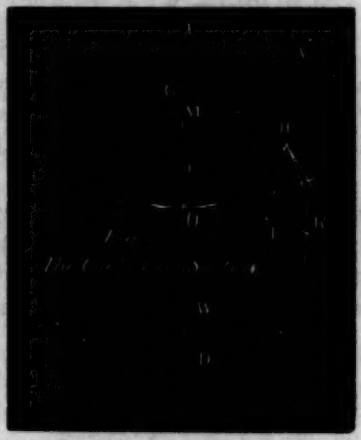
It should be borne in mind that an internal gear is simply a negative gear. The difference between an external and an internal gear is simply a difference in sign, and not in kind.

It must also be borne in mind that the results for internal gears may be vitiated by interference. A three toothed gear will mathematically drive a twelve toothed internal, as Willis claims, but he did not see that the curves would cross and interfere on the approach.

The difference between a spur and a bevel gear is simply a difference in size, from a mathematical point of view. A bevel gear is a spherical gear, and it becomes a spur gear when the diameter of the sphere becomes infinite.

THE CYCLOIDAL SYSTEM.

Bevel Gears.—In *Fig. 2*, which is drawn on a spherical surface, the line of action, $O\ H\ V$, is a circle; and that the flanks of the driven gear shall not be too much undercurved and weakened, it



is customary to limit the diameter of that gear to a certain proportion of that of the circle of action, generally at not less than twice its diameter. We will set the diameter of the circle of action at q times that of the follower, or $2r = qf$.

This gives the angle,

$$H\,G\,O = M = \frac{360\,a}{fq},$$

and the side, $G\ O$; and, from the spherical triangle, $H\,G\,D$, we get the formula,

$$\sin M \cot W = \frac{d}{qf}(1-\alpha^2)+\alpha\beta\cos M \pm (1-\cos M)\sqrt{(1-\alpha^2)(1-\beta^2)} \qquad (3)$$

in which

$$a = \sin GO = \frac{qf}{2R}$$

This formula, which may also be put in the form,

$$\sin H\,G\,O \cot O\,D\,H = \sin(O\,D \pm O\,G)\cot O\,G \mp \cos,(O\,D \pm O\,G)\cos H\,G\,O$$

will solve any case in cycloidal bevel gearing; using the upper sign when the driver is external, and the lower when it is internal. The process for applying it to actual cases is the same as detailed below for spur gears, is not as laborious as the appearance of the formula would indicate, and I will not take space to cite examples.

Spur Gears.—If we put R equal to infinity, the bevel gears become spur gears; $\alpha = 0$, $\beta = 0$, and the formula is reduced to

$$\frac{\sin(M \pm W)}{\sin W} - \frac{d}{qf} \mp 1 = 0 \qquad (4)$$

which will solve any case in cycloidal spur gearing.

It is plain that this formula cannot be solved in general terms, for neither f or d can be separated by any process now known; but it can easily be solved, for any particular case that may arise, by a process of trial and error.

To explain this process, I will give one example in detail. Let the recess be three-quarters of the pitch, the tooth equal to the space, and the flanks of the follower radial; and let it be required to find a follower for an external driver of seven teeth.

This gives

$$a = \tfrac{1}{4}, b = \tfrac{1}{2}, q = \tfrac{1}{2}, d = 7,$$

and the formula becomes

$$\frac{\sin\left(\frac{540^\circ}{f} + 25^\circ\,42'\,51''\right)}{\sin 25^\circ\,42'\,51''} - \left(\frac{14}{f} + 1\right) = 0$$

To solve this, put f at random, at 20, and by the trial, of which I give every figure to show its simplicity, the error is found to be positive.

$$\frac{540^\circ}{20} = 27^\circ$$
$$25^\circ\,42'\,51''$$
$$52^\circ\,42'\,51''$$
$$9{\cdot}9007$$
$$9{\cdot}6374$$
$$0{\cdot}2633$$
$$1{\cdot}834$$
$$\frac{14}{20} + 1 = 1{\cdot}700$$
$$\text{error} = +{\cdot}134$$

and, therefore, 20 is too high.

Then, trying $f = 10$, it is found that the error is negative, and that the true value is therefore between 10 and 20, being nearest to 10. Trying 12, it is found to be between 10 and 12, and finally that it is between 11 and 12. If further accuracy is desirable, trials can be made between 11 and 12 in the same way.

When the follower is internal, f is negative, its flanks are reversed, and the circle of action is internal to the pinion, but there is in reality no change in the mathematical conditions.

From the same formula and by the same process, the driver is found when the follower is given, or the arc of recess when both gears are given. For an example, test MacCord's value of 382 as the least driver for a follower of ten teeth when recess equals the pitch and the follower has radial flanks. Trying 382, the error is negative; for 383 it is also negative, but for 384 it is positive; and, therefore, the latter is the true tabular number. If the formula be used to test MacCord's values for internal followers, the results will be found to agree very well with Willis's table, although it is not practically correct. The trouble with Willis's values is that his flanks are radial, and will, therefore, interfere on the approach, although they are mathematically perfect on the recess, for an internal follower cannot have radial flanks unless the driver is of at least half its diameter. MacCord should not compare his table with Willis's table, as he does, for he has dropped Willis's condition that the flanks shall be radial. According to Mansfield's law of internal interference, the circle of action in this case must be at least as large as the difference between the pitch diameters, and Willis did not have that law.

When either gear is a rack, the formula is reduced to

$$q f = \frac{2\pi\left(a - \frac{b}{2}\right)}{\sin M} \qquad (5)$$

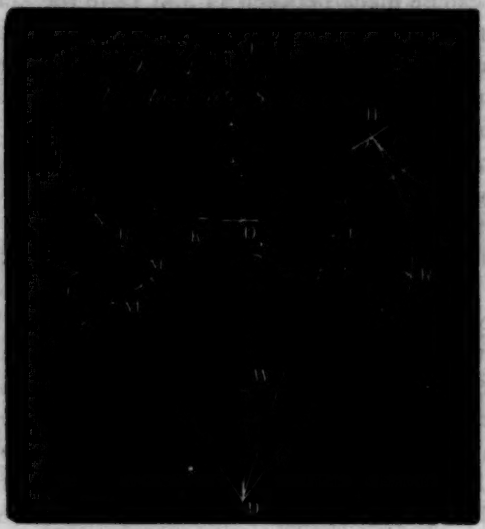
when the rack drives, and to

$$d = \frac{2a\pi}{\tan W} \qquad (6)$$

when it is driven, and these formulæ are to be applied in the same way as the general formula.

THE INVOLUTE SYSTEM.

Bevel Gears.—In *Fig. 3*, which is drawn on the surface of a sphere so that the gears are bevel gears, the line of action is a great circle $M\,O\,H$, and the teeth of the gears are involute in form.



In any limiting case, the point of the tooth must be upon the line of action at H, and the direct object in view is to fix the angle of obliquity, $N\,O\,M = K$, so that that condition is satisfied.

When the angle of obliquity has been determined, we can easily find the least possible driven gear from the known condition that the angle $O\,H\,F$ must be a right angle.

Draw $D\,M$ normal to $M\,O\,H$, and draw the base circle $M\,S$; lay off $R\,S$, equal to $O\,M$, and draw $S\,D$. $H\,O\,M$ is equal to $R\,S\,M$, and, as $O\,M$ is equal to $R\,S$, $H\,O$ must be equal to $S\,M$ The arc of the angle $M\,D\,S$ is equal to that of the angle $O\,D\,R$, and therefore

$$\text{angle } O\,H = \frac{180\ a\ \cos K}{R}$$

and from the spherical triangle $D\,O\,H$, we get the formula,

$$\cot W \cos K = \sin O\,D \cot O\,H \pm \sin K \cos O\,D \qquad (7)$$

from which the maximum value of the angle K can be found by the process of trial and error, as detailed for the cycloidal tooth.

Knowing the angle K, the follower is determined from the triangle $F\,O\,H$ by the formula,

$$f = \frac{2R \tan O\,H}{\sqrt{\sin^2 K + \tan^2 O\,H}} \qquad (8)$$

The upper sign is to be used when the driver is positive and external, and the lower when it is negative and internal.

But, when the recess is less than the circular pitch, it is not sufficient to fix the follower, as above, by the conditions on the recess alone, as can be done with cycloidal teeth. It is the universal custom to restrict the involute tooth to its interchangeable form, in which the angle on the approach is the same as on the recess, and, therefore, we must consider both actions.

The tooth of the driver cannot begin to act until its foot or cusp point arrives at the interference point M, and, therefore, the arc of approach cannot be greater than

$$O\,C' = O\,M\,\frac{\sin O\,D}{\sin M\,D} = \frac{O\,M}{\cos K}. \qquad (9)$$

But, it is plain that in any limiting case the action must commence at M' just at it ceases at H, and, as the whole arc of action, $R\,R''$, cannot be less than the circular pitch, π, and $O\,R$ is equal to $a\,\pi$, $O\,R''$ cannot be less than

$$O\,R'' = \pi - a\,\pi = \pi\,(1 - a). \qquad (10)$$

Therefore, the minimum angle of obliquity allowed by the approach, is given by the formula

$$\tan O\,D \sin K = \tan\left(\frac{\pi\,(1-a)}{R}\cos K\right) \qquad (11)$$

Formula (7) will give a maximum value of the angle K, and (11) will give a minimum. It is plain that the maximum cannot be less than the minimum, and, that when they are equal, the corresponding driver is the smallest possible driver that can be used with the given recess.

Spur Gears.—When the radius of the sphere is infinite, the bevel gears become spur gears, and the formulæ can be adapted by making R equal to infinity. They can also be very easily derived by reasoning, which is so similar to that given for bevel gears that I will not detail it.

The adaptation of formulæ (7) and (8), gives the formulæ

$$\tan K = \mp \left(\frac{a\,\pi}{d}\right) + \sqrt{2\left(\frac{a\,\pi}{d}\right)\cot W + \left(\frac{a\,\pi}{d}\right)^2 - 1} \qquad (12)$$

and

$$f = \frac{2\,a\,\pi}{\tan K}, \qquad (13)$$

which will solve any case in involute spur gearing.

It is to be noticed that this formula is direct, and that it is not necessary to work it by the process of trial and error.

But, if the follower is given and the driver required, we must work it by trial.

As explained in the case of bevel gears, the approach will fix a minimum value for the angle of obliquity, and this angle is given by the formula

$$\tan K = \frac{2\,\pi}{d}(1 - a) \qquad (14)$$

By combining (12) and (14), we can get a value for d, which is the smallest involute interchangeable pinion driver that can be used with the given recess under any circumstances. Thus, when recess equals two-thirds of the pitch, we find that the smallest possible pinion has 5,300 teeth, and that no smaller gear will drive anything. This pinion will drive any gear not smaller than that determined by (12), and it will drive any internal gear that will not interfere with it.* Mathematically speaking, it will drive any internal gear, but when the two are of nearly the same size, the curves will cross each other, and the action will be impossible.

When the driver is a rack, formula (12) becomes

$$\cos K = \sqrt{1 - \frac{b}{2\,a}} \qquad (15)$$

* Prof. MacCord states that the rack is the minimum follower for this minimum driver; see section 243 and the tables of section 276 of his *Kinematics*. It will, however, drive a much smaller follower; the one that is to it, as a is to $(1 - a)$. Thus, when recess is two-thirds the pitch, the minimum driver has 5,300 teeth and will drive a minimum follower having twice as many teeth. When recess is three-fourths of the pitch, the follower will have three times as many teeth, and so on. Prof. M. claims that I have here misrepresented him; but his language is plain, and will bear no other interpretation than that his tabulated followers are the least possible followers for the given drivers.

and when the rack is driven, we have

$$d = \frac{2\,a\,\pi}{\tan W}, \qquad (6)$$

which latter is identical with the same case in the cycloidal system.

On Some Early Forms of Electric Furnaces.

No. 2. Depretz's Electric Furnaces.

By Prof. Edwin J. Houston.

About 1849, Depretz, a member of the French Academy of Sciences, conducted an extensive series of experiments on the fusion and volatilization of different substances. During these investigations he constructed and used furnaces in which the intense heat both of the electric arc and of incandescense, was utilized for the treatment of highly refractory substances.

Depretz's researches were undertaken for the greater part to ascertain whether even the most refractory substances would not fuse or volatilize when subjected to intense heat.

In his earlier experiments he used the electric heat in conjunction with that of other sources; in his later experiments he used the electric heat alone. As a result of his experiments he announced to the French Academy on the 16th of July, 1849, that he had fused and volatilized magnesia and other refractory bodies, and that he had fused carbon. On the 19th of November, 1849, he announced the fusion of silicon, boron, titanium, tungsten, palladium and platinum.

Perhaps the most interesting portion of his researches related to the fusion of carbon, the results of which, for the greater part, are found in his "Fourth Note on the Fusion and Volatilization of Bodies," read before the Academy, at the Seance of the 17th of December, 1849.

In these experiments the electric heat, which alone was used, was furnished by a voltaic battery of 600 Bunsen elements variously coupled according to circumstances. The investigations were singularly complete; carbons from the most varied sources,

such as retort-carbon, carbon obtained from the calcination of sugar, or deposited during the decomposition of spirits of turpentine, anthracite, bituminous coal, graphite, and even the diamond itself.

The mode of application of the heat varied in the different experiments. In some cases the substance was simply placed directly in the voltaic arc, either while in a vacuous space, or while surrounded by an atmosphere of some inert gas. In most cases, however, the substance, in the shape of slender rods, was placed in good electric connection with two carbon holders, that formed the terminals of the battery before mentioned, and was thus raised to an intense electrical incandescence.

In some cases the substances to be exposed to the electric heat were placed in carbon retorts. The positive terminal of the battery was connected to the bottom of the retort, while the negative terminal, attached to a carbon of the same kind as that constituting the retort, was so held as to cause the voltaic arc to play directly on the carbon mass to be acted on by the electric heat. This, it will be seen, constituted an early form of electric furnace of an exceedingly efficient character.

We append the following translation, which we have made of Depretz's description of this form of furnace as contained in his communication of December 17, 1849, before referred to, and taken from vol. 29, of the *Comptes Rendus*, of July–December, 1849:

* * * * * * * * * *

"A small retort of sugar-carbon, about one and a-half centimetres in diameter, was heated by the pile connected in six series of 100 elements, until it was reduced to almost one-third of its volume. The bottom of the retort was covered with a mass of globules of the color of graphite.

"Another experiment did not give so many globules, but we found in one part of the bottom of the retort a bluish-gray plate of graphite as if formed by the union of several flat globules.

"The carbon points, which threw the light into the retort, as well as the holder which held it, were of sugar-carbon."

* * * * * * * * * *

"The two retorts had become soft to the touch, and had acquired the properties of graphite, without, at the same time being so easily made brilliant by friction.

"In these experiments, as in all those in which I had heated a body in a carbon retort, the retort was always made the positive pole, in order that the phenomena of transport could not interfere with the calorific phenomena."

Another form of early electric furnace was devised by Depretz in his experiments on the effect of intense temperatures on the diamond. In this form of Depretz's furnace the source of heat was solely that of electrical incandescence. The substance to be heated was placed in carbon tubes closed with corks of carbon, and the tube was then placed in the circuit of the electric source.

Depretz describes this form of furnace in this communication of December 17, 1849, the translation of which we append:

"As I have seen diamonds exposed suddenly to a strong heat, shivered into fragments, a fact also true for all precious stones, I previously heated the diamonds, which I wished to submit to my trials. For this purpose I shut them up in tubes of carbon of seven or eight millimetres in exterior diameter, closed by corks of carbon.

"In the first experiment, I placed a diamond about two millimetres in diameter, in a tube twenty-three millimetres in length between the two carbon holders.

"The pile was enfeebled by eight days' experiment. At first the tube reddened but feebly, and finally reached a white heat. The experiment was stopped after eight minutes. The diamond had become larger, and of a grayish-black like graphite. It conducted electricity, and left a trace on paper like graphite."

* * * * * * * * * * *

"In the ninth experiment, I placed six small diamonds in a carbon tube seven and three-tenths millimetres in diameter, and thirty-three millimetres in length between the two holders. I had here arranged the pile in twenty-four series of twenty-five elements. The tube was immediately heated to a white heat and I stopped the experiment after seven and a half minutes. Already all the diamonds with the exception of two had been reduced to powder. This powder was without hardness, and marked the fingers and paper like graphite. One of the two diamonds not reduced to powder, immediately became brilliant like characteristic graphite."

Depretz's electric furnaces were, therefore of two types; viz.:

(1.) Those in which the substance was heated by the heat of

the voltaic arc aided more or less by the heat incandescence of the carbon retort in which the substance was placed.

(2.) Those in which the substance was subjected to the sole action of the heat of electric incandescence. It will be noticed that the electric source employed by Depretz, from the number of the elements it contained, placed at his command comparatively powerful electric currents.

No. 3. LONTIN'S ELECTRIC FURNACE.

In the two early forms of electric furnaces, already described, the heat of the voltaic arc or of electric incandescence alone was utilized. Although in the Pepy's furnace the chemical affinity of the heated iron for the carbon of the diamond, undoubtedly aided the operation, and permitted it to take place at temperatures probably far below those Depretz found necessary, and although, in some of the operations of Depretz, notably those in which the voltaic arc, formed between two carbon electrodes, was caused to play on the material to be treated, the chemical affinities of the electrodes were present, and, perhaps, to some extent aided the operation, yet, in neither of these early forms of furnaces, was such chemical action a leading or designed feature of their operation. They aimed at intense heat alone. They provided means for readily obtaining, in a limited space, an excessive temperature that not only permitted regulation as to its intensity, but entirely avoided the introduction of foreign gaseous or sublimed products into the furnace chamber, and thus permitted operations to be carried on that would be impracticable or difficult with furnaces of ordinary construction.

In the furnace of M. D. F. Lontin, we find a designed combination of electrical heat and electrical decomposition. The substances subjected to the operation were rendered electrolyzable either by electric heat or heat of extraneous origin, and were then subjected to the decomposing action of the electric current.

In the Lontin furnace the electric source employed was a dynamo-electric machine of the series type. The idea of the inventor was to place in the circuit external to the machine such a number of his electric crucibles as would by their resistance reduce the magnetization of the field magnets, and thus lessen the resistance to rotation of the machine.

Lontin took out letters-patent for his invention. The following descriptions are taken from his British patent No. 473, of 1875, for the "Application of electro-dynamic machines for obtaining metals, etc.," the provisional specification for which was filed on the 8th of February, 1875.

"It is well known that electricity decomposes metallic salts, and eliminates the metals therefrom, but according to this invention it is proposed to employ only electricity generated by electro-dynamic machines, and collected under the conditions hereinafter explained. Take, for example, an electro-dynamic machine, which, as is well known, generates electricity merely at the expense of motion. In these machines a portion of the electricity developed goes to magnetize the electro-magnets, and the remainder is at the service of the operator. If the proportion of electricity appropriated for magnetization be removed, or if the whole of the electricity produced be so applied (and this is the condition under which it is proposed to operate), the machine may acquire such a degree of resistance to rotation that it can no longer be kept in motion.

"The principle on which this invention is based is briefly stated as consisting in the employment of an electro-dynamic machine, wherein the whole of the current produced by the machine is returned to the primary electro-magnet (simple or multiple), in which circuit are placed what are herein termed the voltameters to be operated on.

"I will now explain the invention more fully. Suppose a break to be made in any of the wires of the machine, its power will thereupon cease, and if the broken wire be reunited, its power is again renewed. If, therefore, the circuit be completed by one or more apparatus, herein termed voltameters, the machine will work, and the substances placed in such voltameter will be decomposed, the resistance of the latter diminishing, to a corresponding extent, the resistance to the rotation of the machine. If now I employ as voltameters heated crucibles containing, for example, double chloride of aluminium and sodium, and two electrodes of prepared carbon, aluminium and chlorine are obtained.

"In these crucibles may be placed any metallic salt from which it is desired to obtain the metal, the completeness of the decomposition exceeding anything hitherto attained.

By the name of voltameters, I designate any apparatus in which are placed one or several chemical substances capable of being decomposed by electricity, and I designate by the name of dynamo-chemical an electro-dynamic machine employed in the manner above specified."

Lontin points out in another portion in the above patent the well-known fact that alternating current machines are unsuited to the work of electro-chemical decomposition, and that therefore commuted or direct current machines must be employed.

Though some of the ideas contained in portions of the patent are somewhat crude, when viewed in the light of to-day, they are nevertheless far from impractical. The similarity of some of these ideas to certain electro-chemical operations carried on to-day are too obvious to need comment.

In a later patent, No. 3,264, of 1876, Lontin claims the right of applying the current produced by other kinds of dynamo-electric machines than the series machine especially referred to in his former patent, as will be seen by the following quotation.

"I reserve the right of applying in all kinds of dynamo-electric machines the principle of sending all the electricity produced by one or more series of coils or induction wheels to the electro-magnets of the dynamo-electric machine, of introducing in a break in the circuit the apparatus in which the desired chemical or magnetic result is to be produced, the principle having been laid down in Patent No. 473, of 1875."

CENTRAL HIGH SCHOOL.

PHILADELPHIA, December 27, 1887.

A NATURAL SCALE AND MEASURE.

By John H. Cooper.

A rule for measuring and the divisions and subdivisions of it should be suited to the needs of the eye and hand.

The lengths of ancient measuring rods were derived from the length of the human arm, or part length of it, as, for instance, the *Cubit*—varying in length from seventeen and one-half to twenty-two inches—which is assumed to be the distance from the elbow to the tip of the middle finger, and the Russian *Arschine*, which is twenty eight inches long, or about the length of the full-grown human arm.

The common *two* and *four-fold* rules should not, in opened length, extend beyond the convenient reach of arm and sight, and the smallest subdivision of the unit upon them for general use should be plainly visible to the unassisted eye.

The standard inch as we now have it, as a fixed unit, should be preserved.

The conclusion is already foregone that the decimal system of graduating rules and scales should be employed and maintained.

In the adoption of the decimal system we shall merely change our usual way of thinking and saying small measures as now in sixteenths, thirty-seconds and sixty-fourths, and express them in tenths and hundredths, as stated by Whitworth, thirty years ago, to be "easy of attainment."

Whatever standard unit may be generally adopted, and however it may be divided, the subdivisions of it can be extended by instrumental means to almost any refinement of reduction by verniers and microscopes.

When the eye is assisted by optical devices, combined with exact mechanical adjustments, any degree of fineness that may be required by the most exacting practice can readily be obtained.

The millimetre is too coarse for a smallest division on the scale, and its subdivision into tenths would be entirely too fine for the eye; much finer than the hundredth of an inch, which is already practically invisible to most eyes. To subdivide the millimetre into halves and quarters would mix the fractional with the decimal systems and introduce confusion.

The human eye will in all probability ever be what it is now, and any scale suited to its present needs will always be right.

I propose taking for a unit of the scale, a space equal to one and a-half of the standard inch and divide this new inch into ten equal parts, subdividing each of these parts again into tenths, whence we will find the hundredth part of the new inch a plainly visible and practically usable quantity without the use of instrumental helps to the eye.

A scale is here given, so divided in order that its least division may be seen in comparison with the standard inch similarly divided.

By the adoption of this scale we shall get rid of those uncertain approximations to the finer fractions, as "*a full 32d;*" "*a 64th a little scant;*" and "*a 32d full scant,*" the smallest measure on the new scale being already reduced to the limit of distinct vision.

It is neither believed, nor urged here, that all the exact dimensions of the fitting parts of machines can be measured by the eye from this new scale, or from any other, nor is the substitution of measures by *sight* for measures by *feeling* here proposed for the extreme niceties of machine fitting.

The superior certainty of *feeling* over eyesight must ever, as is usual, without instrumental aid, remain as a means to be employed for copying minutest measures.

I propose further to use ten of these inches to make the new foot, which will be as long as fifteen of the present standard inches, and the new *two-foot rule* for general use will, therefore, be thirty inches long, which will make a measuring rod in every way more convenient for eye and hand than the Yard-stick, the Metre, or the Four-foot rule.

Philadelphia, October 7, 1887.

[*Contribution from the Department of Civil Engineering, University of Pennsylvania.*]

THE PHILADELPHIA TRACTION COMPANY'S CONDUIT.

BY JOSEPH C. WAGNER.

The question of rapid transit for Philadelphia has been agitating the public mind for years past. The growth of the city in population and in territory renders it more difficult each succeeding year for the horse-car companies to provide adequate means for the transportation of passengers through the city.

In 1882, the Philadelphia Traction Company essayed to provide for rapid transportation by introducing upon their lines of railway, the cable system of traction. It was thought that, although not securing as rapid rates of speed as is obtained upon elevated or underground systems, and though not having as great a carrying capacity as the two systems just mentioned, the cable would, at all events, partially solve the problem presented, and abolish many of the evils of the horse-car system. And all this at an outlay of much less capital than would be required by either an elevated or an underground system.

The cable system of traction for street cars was first introduced into this country in San Francisco, in 1873, on the Clay Street Hill Road. This road was but 2,800 feet in length. The favorable conditions of soil and climate made it a success, and led to its extension in that city, until at present several miles are in operation.

The cost in San Francisco of three miles of road was $155,698, exclusive of the cable and machinery necessary to run it These, together, cost $86,080, making a total of $241,778. The annual cost of running was $59,085, as against $138,880 by horse-power, being a saving annually of $79,795 for three miles = $26,598 per mile.

Chicago was the next city to make a trial of the cable, but its first line was not completed until January, 1882. The conditions at Chicago were much less favorable than at San Francisco. The ground there was soft and yielding, and the iron conduits could be prevented from sinking only by laying them upon heavy beds of concrete. One favorable condition in Chicago, however, was the absence of any considerable grades, the line being almost level.

The only hinderance then to the adoption of the cable system in the East was the question of its success in the Western cities, and the doubt as to its being able to withstand the rapid and varied changes in the Eastern climate.

The Chicago line, immediately after its construction, was thoroughly tested as to its ability to resist severe frosts and snow. It withstood the test very successfully, and there was no further bar to its extension in the East. The figures for the Chicago cable were considerably higher than those for San Francisco, because of the difficulties to be overcome in the soft nature of the soil. The cost per mile was $115,000.

The next city to adopt the system was Philadelphia, where the first line was built on Columbia Avenue, between Ridge Avenue and East Park, a distance of about two miles of single track. The mileage, at present, of the Philadelphia Traction Company's lines amounts to about fourteen or sixteen, and the company is still further extending its system.

The conduits on the Columbia Avenue and Market Street lines seem to have been put down with a singleness of purpose, and that purpose to have been that the cost of the road should be a minimum. The engineering requirements and conditions seem to have been utterly ignored, with the result too well known to all our citizens.

Some of the essential features of the conduit and method of laying, as employed on Columbia Avenue and upon Market Street, will be briefly described. In placing the conduit in its proper position, the cross ties under and connecting the stringers upon which rested the rails, were cut entirely through. This severed all connection between the slot and the rail and thus failed to fulfil two of the most important requirements of the conduit, viz: that the gauge of the tracks should remain constant, and that the system should possess "sufficient rigidity to resist displacement by water, frost, travel and other forces." The road in this faulty condition worked well enough until frost set in. The ground being moist and suddenly freezing naturally expanded, and in consequence a great pressure was brought on the sides of the conduits, which had not sufficient stiffness to resist bending. The slot was consequently almost, and in some cases, entirely closed, so that the grip could not pass between the two edges. The remedy first

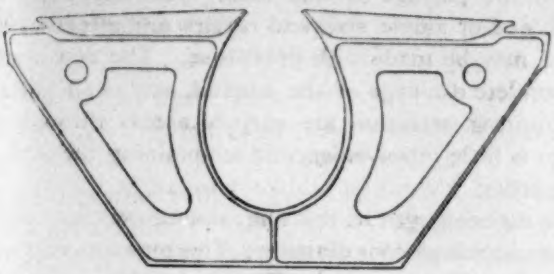
applied was an iron rod, bolted to the upper part of the conduit, running through the string pieces and bolted upon the outside of these. But this availed nothing, and was but useless expense, for the defect was not yet remedied. There was as yet no adequate provision for counteracting the pressure to which the conduit was subjected. The cross ties were not ties, but merely served as foundations for the stringers, and each succeeding frost gave fresh evidence that the gauge of the track could not be maintained constant by the means provided. In consequence of the contraction of gauge, some fifty car axles were broken during the preliminary trips. This tension rod having become inadequate properly to maintain the gauge, other means were sought, and the second proposed changes were of a more scientific and effective nature. The old cut ties were removed and replaced by new ones, one end of the new tie abutting against the upper part of the conduit, and the other end extending beyond the stringer and provided with an iron shoe. An iron rod twice as thick as the old one was bolted to the upper part of the conduit, and, passing obliquely through a hole in the stringer, was bolted to the end of the tie itself, resting on the iron shoe fitted on the end of the tie. The ties being of wood will soon become inefficient on account of rotting, and will have to be renewed. This renewal will have the disadvantage of causing a movement of all the connected parts, thus breaking, for the time, the continuity of the structure. The parts, too, are so situated as not to be easily accessible for repair. The new ties were placed four feet apart. Soon afterward the system was still further braced by the introduction of a tie bolted to the bottom of the conduit and running obliquely up to the upper surface of the new tie. This triangular system of bracing thus formed is undoubtedly "the cheapest and most effective that could have been substituted." The slot itself, however, as amended, does not yet seem to be of sufficient strength to resist the effects of the heavy traffic over it. The shape is faulty and likewise the manner of holding it in place, there being nothing but a single bolt near the end of the lower angle. The thickness of the angles of the slot is too little and the angles themselves are too long to possess sufficient rigidity to resist any great force coming upon them.

The man-hole covers already put down have given evidence of faulty construction. Sufficient allowance for heavy traffic was not

made, and, in consequence, many of them have become warped and unfit for use. Large numbers of these covers have been replaced by new ones of greater thickness. These improvements to a system initially defective, have necessitated an outlay of some $250,000. The initial cost of the road was between $40,000 and $50,000 per mile.

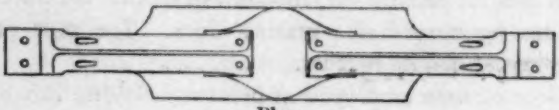
The San Francisco and Chicago systems differ entirely from the system at present in vogue in Philadelphia. The Traction Company is now extending its lines on Seventh and on Ninth Streets, south of Market. The plant there used, however, is widely different in all its parts from the old plant. The new system is patented, but it is practically the same as that used in Chicago. It is in fact an alteration of the Chicago system, without being an infringement on the plan. The conduit consists of a tube of sheet iron ⅛ inch thick and 4 feet 5½ inches in length, bent into a particular shape. The tube is supported by, and bolted to, iron yokes placed 4 feet 6 inches apart between centres. (In the Chicago system the yokes are 8 feet apart.) These yokes are placed with great accuracy, an error of ⅛ inch not being allowable. The yokes rest on beds of concrete about 6 inches deep, and there is a concrete filling around the tubes between yokes. To the yokes are bolted the slots and rails, which are of steel and of peculiar cross section. The slot is bolted to the shoulder of the yoke. Each rail and slot is 31 feet in length. At every 31 feet 6 inches there is a single man-hole, one side of which is similar to one half a yoke, the other side being of special design. Within the man-hole 5 inches below the conduit proper, and on each end of the man-hole, there is a projecting shelf upon which is bolted two channel bars. These channel bars are placed on one flange with the flanges extending away from the centre line of the conduit, and run parallel to this line. Upon these is bolted the pulley and its attachments, over which runs the cable. At every square there is a double man-hole, or "grip-hatch," so called, which extends on both sides of the conduit proper, and is essentially a single man-hole on each side of the centre line of the conduit. These man-holes lie between the track and the slot. The ends of the man-holes take the places of two yokes, supporting the tubes. To these yokes are bolted the sides and bottom—sheet iron plates—thus forming a hollowed square enclosure. Each hole is furnished with a lifting door large

NEW CONDUIT OF THE PHILADELPHIA TRACTION COMPANY.



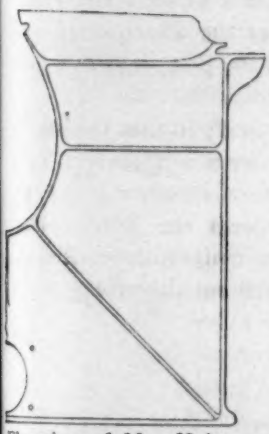
Elevation.

End View.

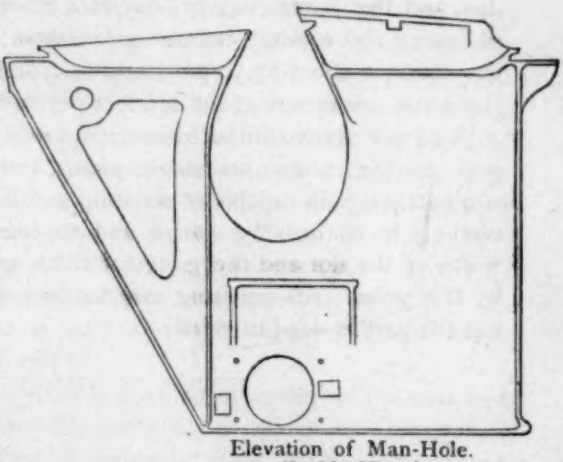


Plan.

(*Scale, 2 feet = 1 inch.*)



Elevation of Man-Hole.
(Outside View.)



Elevation of Man-Hole.
(Inside View.)

(*Scale, 2 feet = 1 inch.*)

Section of Rail and Slot.

(*Scale, One-fourth.*)

enough to allow the passage of one man. The man-holes are easily accessible and of ample size, and repairs and attendance to the pulleys, etc., may be made with great ease. The new system provides for complete drainage of the conduit, and as all parts of the conduit requiring attention are easy of access through the man-holes, there is little inconvenience in maintaining the cable in proper running order.

Running the entire length of the line, and below the conduit, is a nine-inch terra-cotta pipe for drainage. This pipe connects with the sewer at the foot of the grades. The man-holes empty into the pipe, and its mouth is protected from the entrance of large obstructions by means of a grating door. The pipe enters the man-hole just above its bottom.

The force of men employed at present in laying this new plant on Seventh Street is about 250. Each man works ten hours per day, and the lowest pay per day of a laborer is $1.50. The cost of laying the conduit complete, exclusive of the after-paving of the street, is about $2.50 per lineal foot, and the progress made on the work amounts to about 400 feet per day.

The new system differs from the old principally in that the supports for the conduit are single pieces, and form of themselves a single truss, fully capable of resisting any lateral or other pressure tending to change the gauge and to compress the slot. The width of the slot and the gauge of track are maintained constant by this yoke. All repairing may be done without disturbing any but the part in need of repair.

THE IMPORTANCE OF TUNNELS AND CROSS-CUTS IN ANTHRACITE MINING.

BY HENRY A. WASMUTH, M.E.

The southern and middle anthracite coal fields consist of a number of synclinals with flexures or flanks of an average incline of more than 30°. The number of workable coal beds in those synclinals differ, locally, partly on account of their natural deposition and partly on account of erosion, etc., after their origination.

Naturally, the coal beds of six feet and more thick have been selected for exhaustion, principally the Mammoth bed in the southern and middle coal fields, until now about fifty per cent. of the shipments are mined from other beds of the series in the western middle coal field. Large shipments have also been mined from the Lykens coal beds in the western portion of the southern coal field.

It is an irrefragible principle of mining, that those methods of mining are the most to be recommended by which, without disadvantage to future developments, the earliest and greatest returns may be secured. The application of this mining principle is facilitated by the topography of the greatest portion of the anthracite field. The facilities are:

(1) Exposure of the outcrops of numerous coal beds.

(2) Elevation of some outcrops of coal beds to about 800 feet above natural water levels.

The first facility favors the opening of mines on the coal beds by slopes, and the second, mining above water level or natural drainage. The opening of mines by slopes is the predominant practice in the middle and southern coal field; but, the advantage of "tunnelling" at water level has not been appreciated to its value. It is true, that since steam has been employed for drainage, etc., the apparent value of natural drainage has decreased, but in a formation like the southern anthracite field, the crossing of the strata is indispensable for the knowledge of stratification, and where this has been neglected almost entirely by greed for quick returns, in many instances it has been to the disadvantage of

further developments, to be remedied at great expense in the nearest future. In order to prove this, I refer to the principal systems of opening mines in Europe. Where the topography is favorable and paying lifts are in prospect, mining has been carried on by adits on the deposits and across the formation. It is well known, that the carboniferous formation, to a large extent, is overlaid by younger formations in England, and to keep the surface and marl water from the comparatively dry, gently dipping and most regularly deposited coal beds, shafts with cast-iron lining were sunk as early as 1795 to the first workable coal bed, and when this was exhausted, to the next one, etc. It is obvious that the crossing of such strata would be very uneconomical. Similar developments have been adopted for the moderately inclined coal beds in Westphalia; but, where the coal beds dip more steeply, the shafts have been sunk at once for one or two lifts and the strata crossed; also, in France, Belgium, etc. Slopes are rare exceptions now, though cheap at first, they are expensive in the long run, for the output to a certain degree is limited, and wear and tear of hoisting and pumping is greater than by shafts. Whether a mine is opened by a slope or a shaft, the crossing of steep dipping strata in the upper levels secures the knowledge of the geometrical position of the coal beds, and to a certain degree the existence of faulting, and without such knowledge the developments lack the necessary basis.

From this brief review, it will be seen that mining in this country is a repetition of European methods. In the nearly flat anthracite beds of the Wyoming region and the gently dipping bituminous coal beds of Western Pennsylvania, no system will answer so well as the English system; while in the greater portion of the middle and southern coal field, where a series of workable coal beds have been compressed into narrow synclinals and minor rolls, with steep inclined flanks, the German system will prove to be most adaptable, applied already in Middle Creek Colliery, etc. To ascertain the condition of coal beds not yet crossed in this colliery, would require either the continuation of the cross-cut in both directions at the bottom of the shaft, or holes with the diamond drill, but I would not advise the latter, for the question is not to prove the existence of coal beds, but to prove the workable condition of coal beds known to overly the Primrose bed, and also the known series of

beds towards the bottom of the formation, which would be effected by the diamond drill with problematical results. Such a crossing of the strata would give at least three lifts for the beds overlying the Primrose, and at least six levels on the Lykens beds (of course, if in workable condition). To lower such vast amounts of coal from five lifts to shaft level would be very expensive, and a calculation would prove the advantage of first driving an adit to the Lykens series.

The numerous adits in the Panther Creek region are similar to the old and numerous long adits in the southern portion of the coal field in Westphalia. In both regions, the geometrical position of the coal beds has been indicated by those adits, but while the strata are dislocated by faults of both characters in Westphalia, longitudinal faulting is predominant in the Panther Creek region.

The celebrated West Brookside Colliery has been developed to about the elevation of tide level by slopes, and further developments will be necessary in the nearest future. Except a few cross-cuts to the little Lykens and White seams, and a line of shaftings across Bear Valley, about two miles east of Slope No. 4, there is no further information of the geometrical position of the north-dipping coal beds in this colliery, and as the great disturbance of the strata in Williamstown Tunnel certainly will be struck in Brookside also, thus greatly interfering with the little knowledge of stratification of that district, there are no other means to ascertain the geometrical position and workable condition of certainly existing coal beds than either by tunnelling at water level, or sinking shafts and from these crossing the strata. The diamond drill would be of little value in broken and confusedly dislocated strata, known to be at least 1,500 feet long horizontally and no indication where the disturbance will either die out or leave the coal measures to the east. The truth of this will be shown very soon by the new shaft of Williamstown Colliery, in Bear Valley.

From Williamstown Tunnel to Branchdale there are several great disturbances of the strata not represented by any map:

(1) The disturbance in Williamstown Tunnel already referred to, by which most probably the Bear Valley basin and its whole south-dipping flank has been dislocated towards the north, is similar to the dislocation of considerable strata north, exposed in Rhume Run Tunnel No. 1.

(2) The disturbance (most probably by longitudinal faulting) north of Good Spring railroad station.

(3) The disturbance east of Colket Colliery, developed in this and Middle Creek Colliery and the longitudinal fault developed in the latter.

(4) The disturbance of the strata developed by shafting, and, if I remember correctly, also in tunnelling in Swatara Colliery.

(5) The longitudinal dislocation of the whole strata developed in all levels of White Ash slope in Otto Colliery, and most probably another great disturbance in the neighborhood of School Row.

To meet the difficulties of those disturbances in further developments, will require:

(1) The abandonment of the notion of existing inversions in coal beds.

(2) The crossing of the strata, either between two such disturbances, or, for the discovery of the dislocated coal beds, according to the rules.

It is a well-known fact, that in the region referred to, the flexures of the Primrose, Mammoth and Lykens Valley beds in good condition have been mined extensively, and the remaining workable coal beds of the series, not touched yet, will have to be developed very soon by shafts and crossings of the strata, provided that no new system should be devised to accomplish the object more economically.

4128 Elm Avenue, Philadelphia, December, 1887.

A REVIEW OF PROGRESS IN THE ARTS AND MANUFACTURES IN 1887.

[*From the Report of the Secretary to the Annual Meeting of the* FRANKLIN INSTITUTE, *held Monday, January 18, 1888.*]

IN RESPECT to general commercial and industrial activity, the year that has just passed into history has been the most prosperous that the United States has ever known. The hopeful signs of industrial revival, which were visible toward the close of 1885, and which were fully established throughout the year 1886, appear to have reached their culminating point in 1887, in which industrial operations were expanded to hitherto unequalled proportions. As is invariably the case, in the recurring periods of prosperity, with which we have become so familiar, the favoring conditions exhibit themselves most clearly in the various branches of the iron trade. The year 1886, as I had occasion to note in my summary of progress for that year, was characterized at its close as the most prosperous year ever known in the history of the iron industries in the United States, in which, likewise, production in all branches exceeded that of any previous years. The year 1887 was a no less prosperous one for the iron trade and was one of even greater activity. I have the high authority of Mr. James M. Swank, of the American Iron and Steel Association, for the following data respecting the *American iron trade* for 1887, which are abstracted from his annual review. From this it appears that production in all leading branches of the manufacture of iron and steel was the largest in our history—larger than in the remarkable year 1886, when all previous achievements were left far behind. He estimates our production of pig iron in 1887 at 6,417,148 gross tons, or about 800,000 tons more than in 1886, when our production was 5,683,329 tons. Our production of Bessemer steel rails in 1887 was about 1,950,000 gross tons, or about 375,000 tons more than in 1886, when our production was 1,574,703 tons. In addition to our large production of pig iron in 1887 we also consumed about 500,000 tons of imported pig iron, and about 160,000 tons of imported steel rails. Our imports of iron and steel in other forms in 1887 were also very large, the total importations of iron and steel in all forms aggregating nearly 1,800,000 tons. Our production of iron ore in 1887 was about 11,000,000 gross tons, and our imports in the same year amounted to about 1,250,000 tons. In 1886 we produced about 10,000,000 gross tons of iron ore, and imported 1,039,433 tons. In November, 1887, there were in the United States 582 blast furnaces, entitled to be classed as active, the annual capacity of which Mr. Swank estimates at about 11,000,000 tons. Particularly noteworthy is the great activity in the construction of new furnaces during the past year, especially in the Southern States, Tennessee and Alabama, where the development of the iron industries during the past two years has been exceptionally

rapid. Mr. Swank tells us that at the close of November, 1887, there were thirty furnaces under construction, of which no less than nineteen, or nearly two-thirds, were located in Alabama.

The number of rolling mills on the active list in November, 1887, is placed by Mr. Swank at 433, with twelve building, and their annual capacity in finished iron and steel is estimated at 8,265,000 tons. Of special interest are the figures exhibiting the growing application of natural gas for fuel by iron and steel manufacturers. In September, 1884, natural gas was in use in six establishments; in August, 1886, sixty-eight rolling mills and steel works were using this fuel; in November, 1887, this number had risen to ninety-six. (No allusion is made at this point to the use of natural gas as fuel in other manufacturing operations, notably for glass making, in the regions adjacent to the oil-producing territory, in which it has very generally superseded the employment of solid fuel.)

In November, 1887, there were in this country, thirty-five standard Bessemer steel works, with seventy-four converters, and three new plants were in course of erection. The annual ingot capacity of these works (including that of the works now building) is placed by Mr. Swank at 4,750,000 tons.

Of the Clapp-Griffith steel industry, of which great things were predicted a few years ago, Mr. Swank remarks that it has not exhibited much progress since 1886. The first works using the Clapp-Griffith process was erected in this country in 1884; in 1886 the number had grown to six, with two in construction, containing thirteen converters in all; while in November, 1887, there were eight completed works, and one in construction, having in all sixteen converters, and having an annual ingot capacity of 225,000 tons. The open-hearth industry, from Mr. Swank's data, exhibited great progress during the past year. In August, 1886, there were forty-two completed open-hearth steel works in the United States and seven in course of erection. In November, 1887, there were fifty completed works and three in course of erection. The open-hearth steel works in 1886, completed and building, contained eighty-nine furnaces, and, in 1887, they contained 104 furnaces. In 1886, the annual ingot capacity of the works completed and then building was 660,000 tons, and in 1887, it was 815,000 tons. The crucible steel works increased from forty in 1886, to forty-one in 1887, with 3,398 pots.

There was a falling off in the demand for nearly all forms of iron products, which became more and more decided towards the close of the year.

During the year 1887, there were added to the railway systems of the United States, according to the estimates of the *Railway Age*, 12,724 miles of new track. These figures represent main line only, and are exclusive of the large amount added in the form of the side tracks and for renewals. The railway construction in 1887 is the largest ever attained in a single year before, exceeding the figures of the year 1882, in which 11,568 miles were built, and which, it has been repeatedly predicted, would never be surpassed. It may, however, be safely asserted that the year 1888 will witness a decided curtailment of new railway constructions; for it is generally believed that a large proportion of the phenomenal construction of 1887 was built principally for the purpose of occupying, in advance of rivals, at present unproductive, but

prospectively valuable territory. The number of miles of railway in the country at the close of 1887, is placed by the authority above quoted at 150,710 miles.

The domestic *production of coal* in 1887 also reached higher figures than in any previous year. The *Engineering and Mining Journal* estimates the output to have been about 110,000,000 tons, of which 36,626,627 tons were anthracite, and 74,000,000 tons bituminous. Of the last, about 8,000,000 tons were converted into coke. These figures show an increase of about 10,000,000 tons over those of 1886. On the authority of the journal above named, it may prove useful to add the figures of production of the principal metals employed in the industries, all of which exhibit advances over all previous years, to wit: the domestic production of lead, in 1887, was 160,000 tons, as against 143,957 tons, in 1883, which was the largest output previously recorded; of copper, 81,473 tons, in 1887, as against 76,000 tons in 1885; and of zinc, 51,000 tons, as compared with 38,072 tons in 1886.

The aggregate gold product of the United States in 1887, is placed by Mr. John J. Valentine, at $32,500,067, against $29,561,424 in 1886, and is the largest of any year since 1880, when $32,559,067 was produced. The total silver product is given at $50,833,844, which with the exception of the $52,136,851 produced in 1886, is the largest ever known.

IN ENGINEERING, the most prominent subject of discussion was the Panama Canal. Respecting this work, the events of the past year have only served to confirm the belief that has long been entertained among those best qualified to judge, that it was undertaken with an utterly inadequate understanding of the difficulties to be encountered, and that it has been continued with a reckless disregard of consequences, that has no parallel in the history of modern engineering enterprises. The latest reliable information respecting the condition of the work is contained in the official report of Señor Armero, the agent of the Colombian Government, the results of whose investigations of the company's affairs and the state of the engineering operations on September 1st, makes a truly alarming exhibit. He states, in brief, that the total amount of excavations required, according to the company's plans, is 161,000,000 cubic metres, of which up to September 1st, 33,925,230 had been taken out, that the company had expended up to that time, the sum of 818,032,900 francs (considerably more than the original estimated cost of the entire work), and that the most difficult portions of the work have scarcely been commenced. He estimates that to finish the canal, on the original plans of the company, will require an additional expenditure of over 2,000,000,000 francs. The latest utterances of the head of this enterprise, are to the effect that, having in mind the pledges repeatedly made, to have the canal open to traffic in 1890, the plan of a "sea-level canal" will be temporarily abandoned, and a system of locks adopted instead.

At the famous International Congress, in Paris, at which the Panama scheme was enthusiastically agreed on, it was vehemently insisted by De Lesseps and his following, that to fulfil the requirements of international commercial intercourse, a *canal à niveau* was imperatively necessary. Comment thereon is unnecessary.

The fact is worthy of note at this point, that an American Company that has secured a concession for the construction of a canal across Nicaragua, took the first steps near the close of the past year towards putting their plans in operation, by sending out an engineering corps to commence work.

Work upon the great Forth bridge during the past year has been steadily advanced. This will have a total length, when completed, of 8,300 feet. It will have two main spans of 1,700 feet each, and two side spans of 675 feet each. There will be 150 feet of clear way between water level and the central 500 feet.

In this country, the year 1887 witnessed the commencement of work on the much-needed bridge over the Hudson River, at Poughkeepsie, respecting which Mr. Grimshaw furnishes us with the following details: It will have a total length of 6,667 feet, the bridge proper being 3,093 feet. There is from 130 to 160 feet head room, and the structure is entirely of steel, even to the rivets. It will make an almost direct route from Boston and Springfield to Scranton, the anthracite coal fields and Harrisburg. There are four piers in the river; these are of masonry resting on timber caissons dredged down 140 feet below high water. The substitution of steel towers for masonry greatly diminishes the pressure on the foundations, and the substitution of three cantilever spans of 540 feet each, and two connection spans of 525 feet each, for five disconnected spans of 525 feet each, enables the erection of the three cantilever spans without staging in the river, and gives more water way between the piers and a clear height of 160 feet instead of 130 in three of the spans. An important bridge of stone and steel is being constructed over the Harlem River, at One-Hundred-and-Eighty-first Street, New York, which, when completed, will have a length of 2,375 feet, and a height of 151 feet above the water. A bridge across the Missouri, near Kansas City, was nearly completed during the past year. It has three spans of 400 feet each, one of 250, one of 200, two of 175 feet each, and a viaduct of about 2,000 feet in length. It is intended for the Chicago extension of the Atchison, Topeka and Santa Fé Railroad. A fine railway bridge of nine spans across the same river, at Rulo, was built during the year for the Chicago, Burlington and Quincy Railroad.

Work upon the Croton Aqueduct was vigorously pushed forward during the past year, and its early completion may be anticipated. When the improvements to be made in connection with it are completed, it will be competent to supply the city of New York with 200,000,000 gallons of water per day.

An important engineering work, which was undertaken during the past year, is the Holstein Canal, which, when finished, will join the North Sea with the Baltic, and will be of material service to commerce. Certain projected engineering works are worthy of a word of allusion in passing. The

Simplon Tunnel, which has long been talked of, was the subject of some discussion. A proposal has been seriously made to build a submarine tunnel to join Prince Edward's Island with the mainland. The length of the tunnel would be eight miles. The much-talked-of project of tunnelling the English Channel appears, for the present at least, to have been dropped, and for the most extraordinary of reasons—namely, the fear on the part of the English military authorities that it might be captured by their Gallic neighbors, and used as an avenue for the invasion of English territory. Extensive improvements of the Queensland harbors and rivers have been decided upon, and similar improvements are contemplated for the ports of Lisbon and St. Petersburg. In this country, the so-called Hennepin Canal, to unite the waters of the Great Lakes with the Mississippi, has been vigorously advocated; the improvement of the navigation of the Delaware River at Philadelphia has also been discussed, and the project of a ship canal across New Jersey from the Delaware River to the ocean has been revived in the interests of our coastwise traffic.

The projected Manchester ship canal begins at Eastham, on the south bank of the estuary of the Mersey, following its bank thirteen and one-half miles, then almost direct to its terminus in the docks at Salford and Manchester. Locks, docks and sluices will have to be made, railways diverted and carried overhead, roads carried over, drainage and water supplies carried under, ferry approaches made and traffic provided for, jetties and wharves built, miles of new roads and streets made, and along portions of the route walls and fences built equal almost to fortifications. The total length will be over thirty-five miles.

In foreign countries there has been unusual activity in railway construction. Russia is engaged in the extension of a great system of railways in Siberia and her other Asiatic possessions; England is doing the same in India; and Japan added considerably to her railway mileage during the year. In the United States, the Strong locomotive was the subject of much comment. Noteworthy are the exhaustive experiments made by the Pennsylvania Railroad Company with the Urquhart system of burning petroleum as fuel on locomotives, which is in successful operation in Russia. The results obtained appear to be quite satisfactory, but the use of this form of fuel for locomotives has been demonstrated to be impracticable on the score of expense.

The action of the Legislatures of several of the states forbidding the use of stoves in railway cars, called forth many suggestions, and several systems of heating with steam have been experimented with, and with promising results. Of interest in this connection, also, are the successful trials of last year, of a system of continuous brakes for freight train service, devised by Mr. Westinghouse.

Some suggestive operations and propositions in connection with the economical distribution of power, are worthy of notice in recording the progress of the past year. We learn, for example, from Mr. Grimshaw's comments on this subject, that "The Birmingham experiment of supplying power by compressed air is now in successful operation on a small scale. The project of utilizing the waste power of Niagara has been revived, at

least to the extent of intending to transmit 200,000 horse-power through a tunnel having a maximum diameter of thirty feet and discharging 861,000 cubic feet per minute. The maximum head is 124 feet at Port Day. The contract has been awarded. The Stafford prize of $100,000 for a contrivance to convert the flow of the water of Niagara River into practical power, has not yet been awarded. The Hydraulic Power Company has, in London, about twenty-five miles of mains constantly charged with water at a pressure of 700 pounds per square inch. Service is continued without intermission day and night, Sundays and week-days. In many cases, existing pumping machinery has been discarded in favor of the Power Company's water, and lifts and cranes have been modified to render them suitable to its use." And from the same authority I glean that "the past year has been very productive of fast boats. The *New York*, designed for North River service, 311 feet long and 12 feet 3 inches in moulded depth, accomplishes twenty-three miles per hour. The *Now Then*, 85 x 10 x 3¼, has averaged twenty-four miles per hour for 170 miles—the fastest time for a steam vessel for any considerable distance on this side of the Atlantic. The *Queen Victoria*, of the Manks line, is 340 x 39 x 24, gross tonnage of 1,500 tons, engines 6,000 horse-power; steamed 240 miles at an average of 25·62 miles. Thorneycroft & Co. have produced a boat 147½ feet long, making thirty miles an hour. The Thompsons, of the Clyde, are building steamers to surpass the *Etruria* in speed. The Italian iron-clad *Dogali*, 267 x 37 x 14½ feet, has a speed of twenty-three miles; the German war steamer *Greif*, 25⅓. The Thorneycroft torpedo boat for Spain, 147½ x 14½ x 4⅔, has made thirty-three and one-half per hour with tide, and a mean of thirty per hour with and against tide. The Yarrows have built twin-screw torpedo boats for the Italian Government, attaining a mean speed, loaded, of twenty-eight miles. The *Umbria* has run from Queenstown to Fire Island in six days two hours and thirty-seven minutes, the fastest time on record. The Atlantic liners are developing in speed. The ocean transit is made at the average rate of speed of 16·1 knots for the North German Lloyd, 14·8 for the Cunard, 16·8 for the Compagnie Transatlantique, and 14·1 for the White Star and for the Guion. The time of mail transit from Adelaide has been reduced to twenty-seven days five hours, actual time, via Brindisi and the Suez Canal. This includes twelve hours' delay at Suez waiting for the train to Alexandria."

In the Field of Electricity, there has been substantial improvement in many directions. In respect to the methods of generating electric currents, Mr. Edison's suggestion to obtain electricity directly from fuel without the intervention of the steam engine, is worthy of special notice.

Realizing that there was but faint hope of success in improving upon the thermo-pile, which, in its best forms—which are the product of innumerable experiments—yield an extremely low efficiency, Edison has attempted to take advantage of another principle, namely, the varying magnetic capacity of iron at different temperatures. His statement, which covers the essential feature of his invention, is as follows:

"It has long been known that the magnetism of the magnetic metals, and especially of iron, cobalt and nickel, is markedly affected by heat. According to Becquerel, nickel loses its power of being magnetized at 400°, iron at a cherry-red heat, and cobalt at a white heat. Since, whenever a magnetic field varies in strength in the vicinity of a conductor a current is generated in that conductor, it occurred to me that by placing an iron core in a magnetic circuit, and by varying the magnetizability of that core by varying the temperature, it would be possible to generate a current in a coil of wire surrounding this core. This idea constituted the essential feature of the new generator, which, therefore, I have called a pyro-magnetic generator of electricity."

Mr. Edison has constructed such a generator on this principle, and states, respecting its efficiency, "the results thus far obtained lead to the conclusion that the economy of production of electric energy from fuel by the pyro-magnetic dynamo, will at least be equal to, and probably greater, than that of any of the methods in present use." Mr. Edison has also applied the same principle to the construction of a pyro-magnetic motor. It may be of interest at this point to record the fact that the underlying principle of the pyro-magnetic generator was embraced in the thermo-magnetic motor of Houston and Thomson, which was first described in the JOURNAL of the INSTITUTE, for January, 1879.

The efficiency of the *dynamo-electric machine* is so high, that there would appear to be small encouragement for inventors to seek to improve upon it; nevertheless, numerous improvements, though of minor importance, have been proposed, with the view of increasing the duty of the dynamo per pound of material.

The most noteworthy suggestion in relation to the *primary battery*, is that of Mr. Willard E. Case, who has devised a form of cell in which carbon —which in all forms of primary battery hitherto used, has played the part of the negative or unalterable element—forms the positive element of the couple, the other element being platinum. The electrolyte is sulphuric acid to which potassium chlorate is added. The chemical changes taking place in the electrolyte involve the liberation of oxides of chlorine, which attack the carbon. Mr. Wetzler in this relation, calls attention to a new class of voltaic combinations, in which the oxidizable metals are replaced by alterable solutions. In these, solutions are oxidized, and act as electrodes, instead of the oxidizable metals, such as zinc.

The *secondary battery* has received its full share of attention during the past year, but the improvements that have been suggested, relate to details, and no radical improvement is to be noted.

Of the *electric motor* no very pronounced improvements are to be recorded. Their application to city railways, however, attracted an unusual amount of interest during the year. In connection with this subject, the extended trials of the method of employing secondary batteries carried upon the car, to actuate the electric motor, have been made in New York, Philadelphia and other cities, and with satisfactory results. The mode of gearing the motor to the axles of the car is now recognized as an element of the greatest importance, and the relative merits of steel spiral cords, chain gearing, conical discs and

chains, straps and pulleys, spur gearing, friction gear and worm gearing, were warmly discussed. Several ingenious methods for avoiding the use of a slotted conduit in connection with electric railways, employing continuous conductors, were proposed during the year.

In evidence of the rapid introduction of the *electric railway*, the following enumeration of the cities and towns in which it is in use, and which I give on the authority of Mr. T. C. Martin, will be of interest. The cities and towns in which the electric railway is actually in operation, are: Appleton, Wis.—Appleton Electric Street Railway; overhead conductor, four and one-half miles, five motor cars; Van Depoele system. Baltimore, Md.—Union Passenger Railway Company; overhead conductor; Daft system. Denver, Col.—Denver Tramway Company; conduit, four miles; Short-Nesmith series system. Binghamton, N. Y.—Washington Street and State Asylum Electric Railroad; overhead conductor, five and one-half miles; Van Depoele system. Detroit, Mich.—Detroit Electric Railway Company; overhead conductor, two miles, four motor cars; Van Depoele system. Highland Park Railway Company; overhead conductors, three miles, two motor cars. Gratiot, Mich.—Gratiot Electric Railway Company; overhead conductor, one motor car; Van Depoele system. Kansas City, Mo.—Kansas City Electric Railway Company; Henry system. Lima, O.—Lima Street Railway Motor and Power Company; overhead conductor, six and one-half miles, seven motor cars; Van Depoele system. Los Angeles, Cal.—Los Angeles Electric Railway Company; overhead conductor, five miles, four motor cars; Daft system. Montgomery, Ala.—Capital City Electric Street Railway Company; overhead conductors, eleven miles, twenty motor cars; Van Depoele system. Port Huron, Mich.—Port Huron Electric Railway Company; overhead conductors, two and three-quarter miles, three motor cars; Van Depoele system. Scranton, Pa.—Scranton Suburban Railway Company; overhead conductor, two and one-quarter miles, three motor cars; Van Depoele system. Windsor, Can.—Windsor and Walkerville Electric Railway Company; overhead conductor, one and one-half miles, one motor car; Van Depoele system. In the following places lines are being constructed, or under contract: Ansonia, Conn.; Asbury Park, N. J.; Allegheny, Pa.; Dayton, O.; Harrisburg, Pa.; Lakeside, O.; Los Angeles, Cal.; Middletown, Conn.; Mansfield, O.; New York, N. Y.; Pittsburgh, Pa.; Richmond, Va.; San Diego, Cal.; St. Catherines, Can.; St. Joseph, Mo.; Worcester, Mass.; Woonsocket, R. I.; Wilmington, Del.; Wichita, Kan.

In *electric lighting*, the most noteworthy feature of the past year has been the successful introduction of systems of electrical distribution by alternating currents and transformers, of which that known as the Westinghouse system has been the most prominent. The continued growth of electric lighting, both by arc and incandescence, especially the last named, is noteworthy. Of interest is a system of railway car lighting, suggested by Mr. Barrett, which involves the use of both dynamo and storage battery, the latter intended to be charged by the surplus current of the dynamo, and to be called automatically into requisition when any of the cars are detached from the train.

In *telegraphy*, beyond general improvement in existing methods, there is nothing of importance to note.

In *telephony*, the considerable extension of the long-distance lines during the past year is worthy of special notice. The first of the long-distance lines to be opened for traffic was that between New York and Philadelphia, which was put in operation about the beginning of the year. The advices are to the effect that there were at the close of the past year fifty wires, constituting twenty-five circuits, at work between New York and Philadelphia. Of these, some are leased outright to business men and companies; others are divided among a number of business firms, and a number are retained and are operated from public stations for the transmission of miscellaneous business. In New York, I am informed, there are now 130 offices in which there is direct communication with Philadelphia, independent of the metropolitan telephone service, and in Philadelphia there are forty offices in like manner independent of the local city service. During the year, the lines of the American Telephone and Telegraph Company, which is engaged in the long-distance telephone business, have been considerably extended throughout the Eastern States, and from the latest information at my command, it appears that the lines of the company now run through Stamford, Norwalk, Bridgeport, Birmingham, Ansonia, New Haven, Meriden, New Britain, Hartford, Essex and New London, and connection is made with all points on the line of the Southern New England Telephone Company in Connecticut. Before the winter is over, the company expects to have its lines open to Worcester and Boston. Lines to Albany, N. Y., will be finished before winter, and to Washington before spring.

Considerable improvements have been made in apparatus and methods for recording and reproducing speech. Mr. Wetzler, in a report of electrical progress for the year just passed, refers to certain electrical methods devised for this purpose; one, devised by Mr. Irish, and termed an electro-thermal recording telephone, and the other a repeating phonograph, devised by Mr. Hunter; both of them are spoken of in favorable terms.

The substantial improvements that Mr. Edison is thought to have made in his well-known phonograph were widely published and commented upon. Although this apparatus is not electrical, I take the liberty of referring to it here as perhaps the most convenient place. In his new apparatus, Mr. Edison dispenses with the tin foil, and receives the phonograph record upon a hard and smooth cylinder of wax. Other details relate to improvements in mechanical construction, and the employment of an electric motor to obtain more perfect uniformity of rotation. In this field, Mr. Berliner's invention of an instrument, that he terms the "gramophone," is especially worthy of notice. Mr. Berliner receives the impression of the sound waves upon a lamp-blacked surface of plate glass, on which the stylus traces the record in a direction parallel to the surface of the plate, instead of at right angles to the receiving surface, and which offers, therefore, practically no resistance to the movements of the tracing point, as must be the case where tin foil or wax is indented by the tracing point. The phonogram sheet thus obtained—in this case a spiral line exhibiting, on close inspection, innumerable minute

serrations—is used as a photographic negative, from which, by the process of photo-engraving, electrotypes in copper are obtained. This is the permanent record, and by using these upon the reproducing apparatus, the plate, actuated by proper means, will guide the stylus through the intricacies of the spiral line, and, setting up the corresponding vibrations in the diaphragm, cause the spoken words to be repeated. These improvements in the phonograph seem to be very pronounced, and it is not improbable that the phonograph may shortly take a place as important in our every-day business life as the type-writer or the telephone.

DURING the past year, there has been a considerable extension of the *natural gas* territory, and in the states of Ohio and Indiana the discoveries that have been made are considered to be of the first importance to the industrial development of the regions affected thereby. Throughout Western Pennsylvania the multiplication of manufacturing establishments, attracted by the advantages offered by the new fuel, has gone on uninterruptedly, and the changes which it has wrought within the past few years are little short of the marvellous. The appliances for using the gas as fuel for manufacturing and domestic purposes have also been notably improved, and it is now under such complete control and regulation that objections to its employment on the score of danger may be regarded as substantially removed.

IN CHEMICAL TECHNOLOGY, it is a matter of interest to record the successful demonstration, in England, of the utility of the Castner process for producing the *alkali metals*, which was named as a promising innovation in my review of one year ago. Careful trials of the new process, with an experimental plant on a considerable scale, appear substantially to have established the claims of the inventor. The experimental furnace was capable of treating 720 pounds of caustic soda daily, giving a yield, in twenty-four hours, of 120 pounds of sodium. The estimated cost of production, taken from the actual running of the furnace, is eight and one-fourth pence per pound. The manufacture of sodium on the large scale, by this procedure, it is confidently anticipated, will effect the decided cheapening of many chemical and metallurgical products.

The cheap production of the *aluminium* bronzes in the electric-smelting furnace of the Cowles' Brothers, has attracted the attention of military engineers to the suitability of this metal for the manufacture of heavy ordnance. No further advance during the year in the production of aluminium in the Cowles furnace is to be noted; but I am advised that this metal has been made in considerable quantities in Berlin, by the electrolysis of aluminium salts kept in a state of igneous fusion. This process, it is said, has substantially lowered the market price of the metal.

It is worthy of note that during the past year more attention than ever before has been devoted to the *domestic production of sugar* from the beet and

from sorghum. The beet sugar industry has firmly established itself in California, and extensive enlargements of the existing plant in that state are about being made, which will largely increase the production. Important improvements have likewise been made during the past year in the processes for extracting sugar from the sorghum plant, which, it is believed, have overcome the difficulties that have hitherto stood in the way of the profitable production of sugar from this source.

In *photography*, several ingenious suggestions for obtaining an instantaneous or flash light of highly actinic quality for photographic uses, attracted attention. The basis of this light is magnesium in the form of powder, which is deflagrated with the aid of some suitable substance. For this purpose, the proposed method of Dr. Piffard is perhaps the best. He uses preferably a tuft of photographer's gun-cotton upon which the magnesium powder is sprinkled.

In *illumination* (other than electric), the Welsbach incandescent light, brought out during the past year, may be named as the principal item of interest. It is adapted to be used with any non-luminous gas, either water gas or ordinary coal gas rendered non-luminous by admission of air into the burner. It is made by immersing a fine woven fabric of cotton, of proper shape, into a solution containing salts of zirconium, lanthanum, etc., and subsequently burning out the cotton fibre. The resulting product is the mineralized skeleton of the fabric. It affords, when suspended in the flame, a brilliant and perfectly steady light, claimed to yield from two to three times the amount of light yielded by coal gas burned in the usual way, and to be sufficiently durable in service for all practical purposes.

Of miscellaneous inventions of interest, mention should be made of two which were given their first publicity at the meetings of this INSTITUTE, and which give high promise of utility. I refer to Thomas Shaw's invention of an automatic signaling system, for detecting the presence of explosive gases in mines, and preventing loss of life and damage to property; and Mr. Alexander E. Outerbridge's very ingenious process for casting iron and other metals upon lace, embroideries, and the like.

Without entering upon the domain of pure science, which would carry me far beyond the bounds I have assigned to this review, I cannot refrain from mentioning in conclusion a few notable events which the past year has brought out. It is proposed to make the wave length of sodium light the actual and practical standard of length. Stroumbo has devised an ingenious method of recomposing white light from the spectrum colors, and has improved on Sir Isaac Newton's celebrated experiment with a revolving parti-colored disc, utilizing the persistent colors of the spectrum. The spectrum is projected on a white screen, and the prism rotated rapidly until the space swept by the spectrum on the screen is seen as a band of white light. Observations at Lyons seem to confirm the opinion that each period of maximum perturbation of terrestrial magnetism coincides with the passage of a group of solar spots at its shortest distance from the centre of the solar disc.

I may mention, also, that last year the *largest refracting telescope* in the world was completed in Cleveland for the Lick Observatory, Mount Hamilton, Cal. The column supporting the movable parts is of cast iron, 10 x 17 feet at the base, 4 x 8 at the top, and weighs eighteen tons. The steel tube is 4 feet in diameter at the centre and 56½ feet long, tapering at each end to 38 inches. The object lens, made by the Clarks, of Cambridge, Mass., is 36 inches in diameter, and weighs, with its cell, 638 pounds. It is nearly fifty per cent. more powerful than any other yet made. Finally, I may add, that Dr. Wm. Crookes, of London, advanced at the last meeting of the British Association, a most philosophical hypothesis respecting the "Genesis of the Elements," by a species of evolution from an original primal matter, for which he proposes the name of *protyle*.

BOOK NOTICES.

"INDEX OF CURRENT ELECTRICAL LITERATURE."

The American Institute of Electrical Engineers has inaugurated a good work in its publication of the above index. It is the intention to issue this Index with the monthly Transactions. In it will be included the titles of all articles relating to electrical subjects published in electrical and technical journals, and of papers read before various learned societies in this or foreign countries. For ease of reference, these titles will be properly classified.

It is difficult to overestimate the good work that an efficient monthly index of this character can accomplish for the electrical world. Reliable indices in any department of knowledge are always of value to special students. Their value, however, to a great extent, is too frequently diminished by the fact that they are seldom given to the public until the papers or articles they include have lost their novelty, and thus often much of their value.

The above index, however, differs from most in the fact that it is designed to put within ready reach of the electrical world, papers, articles, and discussions showing the present position of the world's progress in electricity. The rapid interchange of thought, and the spread of knowledge as to the directions of greatest activity in matters electrical, cannot, in our opinion, but very considerably excite increased activity.

The first issue of this index covers fourteen printed pages of the Institute's Transactions. The following classes, under which the various articles are indexed, will give some idea of the scope of the work, viz.: Telegraphy; the Telephone; Electric Lighting; Dynamos, Systems of Distribution; Electric Power; Batteries, Electrolysis, Measuring Instruments; Mechanical, and Miscellaneous.

We notice that no attempt at alphabetical arrangement has been made of the topics included under each sub-division. This we think is a mistake. At present, it is true, it makes but little difference, but with the vast number of

titles that such an index must before long include, an alphabetical arrangement will soon become a necessity.

"The index sheets," it is stated "are printed separately, so that they may be detached at once, if necessary. They will all be bound together at the end of each volume of the Transactions."

As the volumes of the Society appear frequently, we would respectfully suggest that each of the sub-divisions of the topics in each volume be printed on a separate sheet; that is, that no more than a single sub-division be placed on a separate sheet or sheets. In this manner it will be possible to rebind the index for any year or number of years, with all the papers belonging to a single topic in one portion of the volume.

We regret to find that the head "Miscellaneous" includes some two and a half pages of titles. This should be avoided; a classification could be adopted to either entirely abolish this head, or greatly to diminish the titles included under it. E. J. H.

NOTES EMBODYING RECENT PRACTICE IN THE SANITARY DRAINAGE OF BUILDINGS. By Wm. Paul Gerhard, C.E. (Van Nostrand's *Science Series*. No. 93.) New York: D. Van Nostrand, 1887.

Mr. Gerhard has here given us a compact manual on the drainage of buildings. We have seldom seen the subject so well handled for daily application. Instructions, precautions, tests and estimates are laid before us in a few small pages. To be more precise, he divides his work as follows: Part I relates to recent progress in house draining; Part II contains maxims; Part III, suggestions for a sanitary code; Part IV, memoranda on the cost of plumbing work. Presumably a handy-book for architects. E.

THE AMERICAN GEOLOGIST. Vol. I, No. 1. January, 1888.

The first number of this new journal is upon our table.

In its introduction, the need of an exclusively geological journal in the United States is set forth; one "which shall be open to the properly-worded opinions of all, from the most powerful to the most obscure, and which is distinctively committed to no theory." The editors are men of mark in the science, and have the ability to make the journal successful, if the general interest on the part of the cultivators of this science shall be sufficient to sustain their enterprise with the liberal subscription list they deserve.

The first article is devoted to a short history of the origin and acts of the International Congress of Geologists, by Dr. Frazer. Following this are valuable articles by Prof. Winchell and by Dr. Winchell, on the Animike, a formation of great economic importance, including as it does some of the richest, purest and most valuable iron ores of the United States in vast quantity.

Of the other interesting articles, our space forbids mention of more than two. "The Future of Natural Gas," by Prof. Claypole. His views will

probably be upheld by geologists, though very disappointing to the many who think they have in natural gas an unfailing supply of the best and cheapest fuel. Prof. Colvin contributes notes on formations passed through in boring a deep well at Washington, Ia. This well, in a depth of about 1,200 feet, passed through an interesting series of rocks.

In conclusion, it may be said that if the future numbers equal the present one in interest and value, the subscribers will have no reason to complain.

T. D. R.

THE TREATMENT OF SEWAGE. By Dr. C. Meymott Tidy. (Van Nostrand's *Science Series*. No. 94.) New York: D. Van Nostrand, 1887.

Originally this paper appeared in the *Journal of the Society of Arts*, and it has justly been deemed worthy of republication in Van Nostrand's *Science Series*. The author, Dr. Tidy, has been long identified with the sewage question, more particularly as a chemist than as an engineer; yet his work will prove instructive to professional engineers who might wish to arrive at the best opinions held in England regarding the disposal of sewage. The method by precipitation and purification is undoubtedly that which the author considers the most suitable under the conditions prevailing in England. Bearing on this method, he notes certain important details indispensable to its successful application. The method by irrigation does not meet with favor in his eyes. Much information, independent of any process of sewage treatment, is contained besides in the paper. The reader should bear in mind that the conditions of climate, soil, geography and population are very different in England from those on the Continent and in America, and he should realize well these conditions before forming an opinion on the sewage question as viewed by our English cousins. In fact, this precaution has a general application to all engineering problems, but is especially required in studying the treatment of sewage in England. We recommend, in conclusion, this little work to American engineers, who will certainly be called upon to face the difficulties confronting European engineers, when our municipal works shall be regarded as scientific studies instead of political spoils.

E.

SCIENTIFIC NOTES AND COMMENTS.

CHEMISTRY.

ON THE OXIDATION OF SILVER.—H. Le Chatelier (*Bul. Soc. Chim.* **48,** 342). Since, according to the calculations of Thomson, the oxidation of silver disengages fourteen calories for one molecule of oxygen, the combination should take place directly, as in the case of most other metals. Heretofore this has not been accomplished. According to the laws of chemical equilibrium, the decomposition of silver oxide and the oxidation of the metal must be limited at every temperature by the fixed tension of oxygen. Hydrogen does not combine with oxygen at a temperature below 500°, and the direct oxidation of silver would require a calculated temperature of about 327° with a plus or minus error of 60°. The minimum temperature necessary for the oxidation of silver should be the same as the minimum temperature of decomposition of the oxide, and it is known that the oxide begins to decompose at about 250°. One gramme of pure silver was sealed in a hard glass tube with some potassium permanganate, but separated from it by a plug of glass-wool. Under such conditions, the oxidation takes place distinctly at 300°, as is indicated by the black color of the oxide, while the tension of the oxygen does not exceed fifteen atmospheres. The oxidation cannot be made complete, the largest proportion of oxide formed being five decigrammes for one gramme of silver. W. H. G.

COMPOUNDS OF ORDINARY ALCOHOL WITH WATER.—Mendeleeff (*Jour. Chem. Soc.* **51,** 778) has, by a study of specific gravities of mixtures of alcohol and water, arrived at the conclusion that there are three definite hydrates, containing respectively three and twelve molecules of water to one molecule of alcohol, and three of alcohol to one of water. The first of these has been obtained in the crystalline form at the temperature attained by a mixture of solid carbon dioxide and ether; the second solidifies at —17°. W. H. G.

THE ALCOHOLIC PRODUCTS OF THE FERMENTATION OF GLYCEROL UNDER THE INFLUENCE OF BACILLUS BUTYLICUS.—Charles Morin (*Bul. Soc. Chim.* **48,** 802) has extended the studies of Fitz on the fermentation of glycerol by the bacillus butylicus, and submitted thirty kilogrammes of glycerol to the fermentation in seven operations, each on 150 litres of liquid.

He obtained 3,028 grammes of mixed alcohols, which were separated into the following fractions:

	Grammes.
Ethyl alcohol,	384
Normal propyl alcohol,	482
Normal butyl alcohol,	2,027
Normal amyl alcohol,	131
Residue,	4

The formation of normal amyl alcohol had not been noticed by Fitz. It boils at 137° to 138°, and yields an iodide boiling at 154°. The fermentation of glycerol by bacillus butylicus thus yields a series of normal alcohols, a phenomenon which is characteristic of the microbe. W. H. G.

A NEW APPARATUS FOR FRACTIONAL DISTILLATION IN LABORATORIES.—Edouard Claudon and Charles Morin (*Bul. Soc. Chim.* **48,** 804). This apparatus, for a full description of which we must refer to the original, is constructed of brazed copper, and, according to the liquid to be distilled, is capable of fractionating from four or five to nine litres in an hour as perfectly as a Le Bel and Henninger apparatus of fifteen bulbs. It is provided with tell-tale pressure gauge and regulator, level, emptying stop-cock, froth arrester, sample density gauge, and tell-tale for indicating a full bottle of distillate.

W. H. G.

THE DECOMPOSITION OF HALOGEN HYDRIDES BY OXYGEN IN SUNLIGHT.—Arthur Richardson (*Jour. Chem. Soc.* **51,** 801).—The author finds that "in sunlight the stability of the moist hydrides of chlorine, bromine and iodine is dependent on the mass of oxygen present in excess of that required for their complete decomposition;" the larger the excess of oxygen, the larger the proportion of hydracid decomposed. Even in presence of a large excess of free oxygen, the hydrides of chlorine and bromine are not decomposed when dry or nearly dry. On the contrary, dry hydrogen iodide is decomposed by oxygen under the action of sunlight.

W. H. G.

ON THE MIXTURE OF ALDEHYDE AND WATER.—W. H. Perkin (*Jour. Chem. Soc.*, **51,** 816) has studied the density and magnetic rotation of a mixture of aldehyde and water in equi-molecular proportions, and the thermic phenomena at the moment of mixing. If the temperature of the liquids and atmosphere be not higher than 8° or 9°, the temperature first falls and then rises for a long time. In an experiment with twenty-two grammes of aldehyde and nine of water, the temperature at first fell from 7°.46 to 5°.95; it then began to rise, and

After 1 minute was	8°.8
" 2 minutes,	11°.0
" 4 "	14°.7
" 8 "	17°.5
" 12 "	18°.15
" 16 "	18°.4
" 20 "	18°.53
" 24 "	18°.58

It then began to fall very slowly. On attempting to determine the density of the product, the results at first were not concordant, and it was found that when the mixture is subjected to a change of temperature, its volume does not become constant at the new temperature in less than two and one-half or three hours; so that the product must be kept in the density tube during this time before adjusting its volume. The densities are—

$$d\,\frac{0°}{4°} = 0{\cdot}9861 \qquad d\,\frac{6°}{4°} = 0{\cdot}9603 \qquad d\,\frac{13°}{4°} = 0{\cdot}9330.$$

The expansion thus found is greater than that of aldehyde, whereas it should be less were the liquid a mixture of uncombined aldehyde and water, and there is no doubt that the reduction of volume by cooling is owing principally to chemical combination, while the expansion at higher temperatures is chiefly owing to dissociation.

Monohydrated aldehyde does not solidify in a mixture of snow and hydrochloric acid. Its specific magnetic rotation at 15°·7 is 0·8937, the molecular rotation being 3·324; subtracting from this the value of the aldehyde = 2·385, the remainder is 0·928. As this is less than 1, the value of the water, it may be concluded that chemical union has taken place to some extent in the liquid, which therefore contains ethylidene glycol, the proportions varying with the temperature. W. H. G.

PHYSICS.

THE PAILLARD NON-MAGNETIZABLE WATCH.—At the stated meeting of the FRANKLIN INSTITUTE, held Wednesday, January, 18, 1888, Prof. Edwin J. Houston gave, by invitation, an account of some experiments, made by him on the Paillard palladium hair springs and compensating balance wheels for watches. He stated that these experiments convinced him that the palladium alloys employed in the springs and balance wheels examined were destitute of magnetic properties, and that a watch whose balances and hair springs were made of such alloys was not sensibly affected by bringing it near powerful dynamos, nor by subjecting it to extremely powerful magnetic fields.

The Paillard watch examined contains magnetizable material, such, for example, as the steel main spring and steel screws, the springs for the hunting case, etc., etc.

Though magnetism produces no sensible effect on the rate of the watch through the direct magnetic acceleration or retardation of the balance, the question arises whether the movements of the hair spring and balance wheel in the magnetic field might not, like the moving wire in a dynamo, produce a sensible retardation of the watch.

Such retardation might arise in two ways, viz.:

(1) From the permanent field of the watch, due to the magnetization of its magnetizable parts.

(2) From the more powerful extraneous fields into which the watch may be brought.

The first influence does not appear to produce any sensible effect on the rate. The second influence will be experimented on more fully, and a description of the experiments made will be published in a subsequent issue of the JOURNAL of the INSTITUTE. W.

METALLURGY.

THE USE OF STEEL CASTINGS IN LIEU OF STEEL FORGINGS FOR SHIP AND MARINE ENGINE CONSTRUCTION.—In a paper recently prepared by Mr. Wm. Parker, Chief Engineer Surveyor of Lloyd's Register of Shipping, and printed in the *Journal* of the Iron and Steel Institute, some interesting statements are made. It is well known that large forged stern frames and rudder frames are seldom absolutely sound, and that the mortality of wrought-iron crank shafts is excessive.

The superiority of mild steel over iron for the structural parts of ships is now undoubted, and for marine boilers steel has to a very great extent replaced iron. The application, for their approval of the use of cast steel for stems, stern frames, rudders, tillers, quadrants, crank shafts, etc., decided the committee of Lloyd's Register to investigate the physical properties of the material intended to be used, whether the processes used in the manufacture were such as could be expected to secure certainty of results, and to consider what tests would be practicable to determine the quality of the material after the castings have been made.

Tests were made on samples cut from castings, upon the castings themselves, and, for comparison, on forged iron and steel. The results convinced the committee that "structures can be made of cast steel as fit for the purpose intended as those usually made from wrought iron" without the uncertainty associated with the large number of weldings required in making iron forgings.

Inquiries of different manufacturers showed that the methods used, which were the results of their varied experiences, differed widely from each other. Messrs. W. Jessop & Sons melt their steel entirely in crucibles, believing that if it is melted in large masses, as in the Siemens furnace, the metal is not homogeneous enough for structures requiring perfect homogeneity and freedom from molecular strains in every part. Messrs. J. Spencer & Sons use both crucibles and open-hearth furnaces, the size of the casting alone being their guide, while the Steel Company of Scotland use the open-hearth furnace in all this work.

At Messrs. Jessops' the opinion is held that the careful and uniform cooling of the original casting is the only means of ensuring molecular equilibrium, and that (after the casting has become cold) subsequent heating is injurious. All the other steel makers anneal their castings by slowly and uniformly raising the temperature of the casting to that of a bright-red heat, keeping it at that for a length of time and slowly and uniformly cooling it.

Mr. Pourcell, of Terre Noire, attaches importance not only to annealing, but also to tempering castings in oil to increase their ductility. Four specimens, cut from a casting made at Terre Noire were tested. The first, as when cut from the casting, broke at 32·07 tons per square inch, with an elongation of sixteen per cent. in five inches; the second, after annealing, gave 33·7 tons and seventeen per cent.; the third, annealed and tempered in oil, 38·6 tons and seventeen per cent.; the fourth, being twice tempered in oil, gave 41·1 tons, fifteen per cent.

A number of tests of the tensile, bending, percussion and torsional strength of cast steel were made, and the conclusion reached was that while cast steel could be made as reliable as wrought iron, forged steel surpassed in ductility anything that has been yet attained in castings.

As to the quality of cast steel for crank shafts and other engine work, the tensile strength should not exceed thirty tons per square inch, and a piece one and one-fourth inches square should stand bending, cold, through 90°, over a radius not exceeding one and three-fourths inches. H. W. S.

COMPETITIVE TESTS AT WATERTOWN ARSENAL OF BRONZE, AND ALUMINIUM BRONZE AND BRASS.—There have just been completed at the Watertown Arsenal some interesting tests of alloys, which the Government had ordered, with a view to getting the best possible material for the screws for the fifteen or twenty new war ships now building. The results are as follows:

ALUMINIUM BRONZE AND BRASS.

Bronze Composition.	*Pounds Elastic Limit.*	*Per Cent. Elongation.*	*Pounds Tensile Strength Per Square Inch.*
Copper and 8 per cent. Al and Si, . . .	19,000	23·7	58,500
Copper and 10 per cent. Al and Si, . . .	33,000	3·2	68,000
Copper and 8½ per cent. Al and Si, . .	18,000	26·	61,000
Copper and 7½ per cent. Al and Si, . .	19,000	9·3	52,000
Copper and 7 per cent. Al and Si, . . .	17,000	11·9	46,000
Copper and 8¼ per cent. Al and Si, . .	24,000	13·3	66 500
Copper and 9 per cent. Al and Si, . . .	28,000	4·5	66,000
Copper and 10¼ per cent. Al and Si, . .	33,000	3·6	72,500
Brass Composition.			
Copper and 3½ Al, 33½ per cent. Zn, .	55,000	1·6	70,000
Copper and 3½ Al, 33½ per cent. Zn, .	65,000	2·5	82,500

GOVERNMENT GUN BRONZE.

	Elastic Limit.	*Per Cent. Elongation.*	*Pounds Tensile Strength Per Square Inch.*
Copper 88, tin 10, zinc 2, per cent., . . .	9,000	1·5	18,000
Copper 88, tin 10, zinc 2, per cent., . . .	10,000	2·	18,000
Copper 88, tin 10, zinc 2, per cent., . . .	13,000	3·	20,000
Copper 88, tin 10, zinc 2, per cent., . . .	11,000	5·	22,500
Copper 88, tin 10, zinc 2, per cent., . . .	13,000	1·5	23,000
Copper 88, tin 10, zinc 2, per cent., . . .	10,000	3·5	19,000

All bars were 22 inches in length by 1⅛ inches in diameter, and 10 inches or 15 inches between elongation marks. The Government gun bronze was made at the Navy Yard, and is the material that has been used universally in both the Army and Navy Departments in the construction of all bronze cannon, propeller wheels, gun carriages, etc., for the past fifty years. The above tests were made at the Watertown U. S. Arsenal, Watertown, Mass., under the auspices of the United States Navy Department, during the week ending December 13, 1887. W.

ENGINEERING.

THE PROPOSED NORTH RIVER BRIDGE AND TERMINAL STATION AT NEW YORK.—At a recent meeting of the American Society of Civil Engineers, the eminent bridge builder, Mr. Gustav Lindenthal, submitted a project for increasing the terminal facilities of the railroads to Jersey City, and reducing the time and risks of the transfer to New York by ferry, by the construction of a six-track supension bridge over the Hudson River, and a short piece of track connecting it with a large depot 400 x 1,000 feet, situated above Eighteenth Street and near Sixth Avenue.

The bridge would have a single span, between pier lines, of 2,850 feet, and be 145 feet in the clear above high water. The entire length, with the approaches, would be about 6,600 feet.

Except for its magnitude, there is nothing experimental in the project, which it is estimated will require five years to complete, and will cost for the terminal station, viaducts, bridge, tunnel and railroad complete, in all about four miles long, ... $23,000,000
The right of way and incidentals, ... 14,000,000

Total, ... $37,000,000

The estimated net annual revenue from the travel "in sight" at the present time, and from rentals, for the first year, is $2,200,000. The design is a stiffened suspension bridge, consisting of parallel cables connected by triangular bracing, as in the bridges of the Schnirch system at Vienna.

To give a better idea of the grandeur of its dimensions, a comparison may be made with the present familiar but unprecedented structure spanning the East River, which is 5,989 feet long, having a clear span, between piers, of 1,595 feet, and a height above water of 135 feet at the centre. Its weight is about 3,600 tons and load 1,400 tons when covered with people and cars, making a total of 5,000 tons. There are four cables each fifteen and one-half inches diameter, and having an ultimate strength of 11,200 tons.

The desirability of a more reliable connection between the shores of the North River was felt as long ago as 1811, when Thos. Pope, an architect of New York, proposed a single span bridge over this broad expanse of water, but he was far in advance of his time. The Hudson River tunnel is another attempt to solve the problem. Still another was a rolling traveller intended to carry an entire train at one time, as described and illustrated in *Engineering News*, of February 23, 1884. Of these several bridge projects, that of Mr. Lindenthal appears the most promising. L. M. H.

A Series of Tests of the Westinghouse Freight-train Brake, similar to those made in other sections of the country, were made on Saturday, November 26th, on the line of the Pennsylvania Railroad, on a portion of the track near Wynnewood Station, in the vicinity of Philadelphia.

From the *Railway World*, of recent date, we make the following abstract:

The train consisted, as in former tests, of fifty freight cars, closely coupled together, each thirty-eight feet four inches in length. In the first test the train, while running at twenty-three miles per hour, was stopped in fourteen and one-half seconds, and a distance of 264 feet. In the second test, the velocity was thirty-six miles per hour; time required to stop, nineteen and one-half seconds; distance, 593½ feet. In the third test, the brakes were applied to the rear cars of the train in about two seconds. In the fourth test, the absence of serious jarring was demonstrated by the presence of passengers on portions of the train, when it was stopped in eighteen and three-fourths seconds, in a distance of 579 feet, while it was running at the rate of thirty-six miles an hour. In the fifth test, the length of time from the stoppage of the train by the brakes, until they were released and the train again started, was three seconds. In the sixth test, five workmen stopped the train in a distance of 1,883 feet. In the seventh test, the train was suddenly broken and the two sections stopped in thirteen seconds, with only thirty-five feet between the sections. In the eighth test, the full power of the brakes was applied to a

train of twenty cars, and while it was running at a rate of twenty and one-half miles per hour, it was stopped, in six seconds, in a distance of eighty-seven feet. The ninth test consisted of a competitive trial with a passenger train, both running at a speed of forty-nine and one-half miles an hour. The freight train was stopped in a distance of 648 feet in nineteen seconds. The passenger train was stopped in twenty-eight seconds and a distance of 932 feet.

As in the preceding tests, conclusive evidence was afforded of the solution of the continuous freight-train brake problem. The fact that it has been solved is of immense importance to the railway interests of the country, whether the subject is viewed from a humanitarian or financial standpoint. The prevailing method of stopping freight trains is probably the weakest point in the mechanical and personal methods applicable to rolling stock and train movements. The reform contemplated, in conjunction with the adoption of an effective automatic coupler system, which will naturally be an accompaniment, forms one of the greatest advances in the practical every-day movements of railroads that has ever been made. An astute foreign railway expert, who found much to admire in American rolling stock, after visiting many portions of the country, denounced the mode generally adopted here of stopping long and heavy freight trains with hand brakemen as a barbarous practice. It not only subjects those men to numerous dangers, which often lead to serious or fatal injuries, but partly on account of the great risks they must incur if they meet all requirements, and partly for other reasons, there are many accidents to freight trains attributable to defective brake-power. The losses from this source represent a sum much greater than any increase of interest or other current outlay that could occur from the adoption of the improved continuous freight-train brakes. By their use, also, it would be safe and practicable to move many freight trains at a higher rate of speed than is now attainable, and thus the amount of work performed by each freight car might be materially increased. The latter consideration should receive due weight in connection with the incessant demand for new cars and the doleful complaints of car famines whenever commercial movements are exceptionally active. It rarely happens that a new invention is at once so complete, and so well calculated to meet pressing needs in wide fields of usefulness, as the improved Westinghouse continuous freight-train brake. W.

MISCELLANEOUS.

THE MAGELLANIC PREMIUM.—The American Philosophical Society at a regular meeting held December 16, 1887, awarded the Magellanic Premium to the author of a paper entitled "On some of the Physical Phenomena of Harbor Entrances" signed by "Magellan." On opening the sealed envelope which, in accordance with the regulations of the Society, contained the name of the author, it was found to be Prof. Lewis M. Haupt of the University of Pennsylvania. E. J. H.

Franklin Institute.

[*Proceedings of the Annual Meeting, held Wednesday, January 18, 1888.*]

HALL OF THE INSTITUTE, PHILADELPHIA, January 18, 1888.

JOSEPH M. WILSON, President, in the Chair.

Present, eighty-seven members and eight visitors.

Additions to membership since the last report, nine.

The annual report of the Board of Managers was read, as follows:

ANNUAL REPORT OF THE BOARD OF MANAGERS FOR THE YEAR 1887.

The Board of Mangers of the FRANKLIN INSTITUTE of the State of Pennsylvania for the Promotion of the Mechanic Arts, respectfully presents the following report of the operations of the INSTITUTE for the year 1887.

MEMBERS.

Membership at the close of 1887,	2,222	
Number of new members elected, who have paid their dues,	101	
		2,323
Lost by death or resignation,	68	
Dropped for non-payment of dues,	100	
		168
Total membership at close of 1887,		2,155

FINANCIAL STATEMENT.

Receipts.

Balance on hand January 1, 1887,		$1,100 95
Contributions of members,	$4,677 50	
Received from Guarantee Fund on account of loss incurred by Exhibition of 1885,	823 08	
Sales of property, Exhibition of 1885,	960 00	
Legacy of Henry Seybert (deceased),	2,000 00	
Certificates of second class stock,	70 00	
Fund for completion of serials,	1,130 00	
Interest on investments,	737 00	
Cash from Sale Allotment Pennsylvania Railroad Stock,	64 50	
Cash from other sources,	7,928 99	
		18,391 07
		$19,492 02

Payments.

Committee on Library,	$1,524 87	
Committee on Instruction,	2,566 45	
Exhibition of 1885,	131 12	
Salaries and Wages,	4,423 93	
Maintenance and repairs to building,	1,686 18	
Insurance,	300 00	
Paid on account of temporary loan,	2,000 00	
Interest on temporary loan,	177 36	
Other expenditures,	5,483 62	
		18,293 53
Balance on hand December 31st, 1887,		$1,198 49
Remaining to be paid on temporary loan,	$3,000 00	

An examination of the financial statement will show that the deficiency for the year in expenditure over receipts is very considerable, although apparently the balance on hand remains nearly the same. This is owing to the fact, as may readily be seen, that some of the sources of income are casual for the present year only, and will not obtain in the future, also that moneys have been received for special purposes, such as for completion of serials, and not yet expended. Such funds cannot be applied to maintenance of the INSTITUTE.

The legacy of Henry Seybert (deceased) has been invested as a nucleus towards a "Building Fund."

LIBRARY.

The Library has been increased during the year 1887, by the acquisition of over 3,000 additional titles.

The designation of the Library of the FRANKLIN INSTITUTE by the Department of the Interior as a depository of the publications of the Government, will add to its importance as a library of reference.

For additional details respecting this branch of the work of the INSTITUTE the Board refers to the report of the Committee on Library.

THE JOURNAL.

The JOURNAL of the INSTITUTE has shown itself more than self-supporting during the past year, and its condition is very encouraging.

During the year, the Committee on Publications issued a circular-letter, announcing its intention to publish an index covering the first 110 volumes from 1826 to 1880, inclusive, and inviting subscriptions thereto. The responses to this invitation have been so numerous that the Committee can now undertake this important work without risk of financial loss. By the direction of the Board, the printing of the index will be proceeded with at once, and the work will shortly be ready for distribution to subscribers. This publication will add greatly to the usefulness of the JOURNAL as a work of reference.

The voluntary services of collaborators, which were secured for the JOURNAL last year by the Committee on Publications, have been of considerable advantage, and the thanks of the INSTITUTE are due for this valuable aid.

The Board desires again to call attention to the fact that the JOURNAL is not as generally sustained by the members of the INSTITUTE as it should be, and takes this opportunity to ask for it a more generous support at their hands.

LECTURES.

The following Lectures were delivered during the past year, viz.:—By Prof. C. Hanford Henderson, *one*, on "The Bessemer Steel Process and its Modifications," and *one* on "Glass Making;" by Prof. Chas. F. Himes, *one*, on "The Stereoscope and its Applications;" by Miss Helen C. DeS. Abbott, *one*, on "Plant Chemistry as an Applied Science," and *one* on "The Chemical Basis of Plant Forms;" by Mr. John M. Hartman, *one*, on "The Crucible of the Blast Furnace;" by Prof. Frances Emily White, *one*, on "Hygiene;" by Prof. Henry Trimble, *one*, on "Tannin and its Sources;" by Mr. John Birkinbine, *one*, on "Rainfall and Water Supply," and *one* on "Iron Smelting in the United States;" by Prof. J. Burkitt Webb, *one*, on "Mechanical Paradoxes;" by Mr. Carl Hering, *one*, on "Electricity," and *one* on "The Electrical Transmission of Energy;" by Mr. Wm. F. Durfee, *one*, on "Hero of Alexandria, and the Arts and Mechanism of his Time;" by Prof. Luigi D'Auria, *one*, on "Tidal Rivers;" by Mr. C. O. Mailloux, *one*, on "The Storage of Electrical Energy;" by Commander J. R. Bartlett, *one*, on "The Physical Geography of the Sea;" by Capt. O. E. Michaelis, *one*, on "The Army of Kukuanaland;" by Dr. Persifor Frazer, *one*, "Introductory to the Course on Chemistry;" by Prof. Lewis M. Haupt, *one*, on "Rapid Transit in Cities;" by Prof. Wm. H. Greene, *one*, on "The Mechanics of Chemistry;" by Mr. Chas. E. Emery, *one*, on "Steam Heating in Cities;" by Prof. S. P. Sadtler, *one*, on "Russian and American Petroleum," *one*, on "Present and Prospective Sources of Sugar," and *one* on "The Manufacture of Artificial Dye Colors;" by Mr. C. J. Hexamer, *one*, on "The Yellowstone Park;" by Prof. Wm. A. Anthony, *one*, on "Electrical Measurements;" by Thomas Pray, Jr., *one*, on "The Cotton Fibre;" by Mr. John Birkinbine, *one*, on "The Iron Ores of the United States;" and by Prof. J. E. Denton, *one*, on "The Construction of the Great Croton Aqueduct."

The foregoing list embraces thirty-two lectures. The Professors of the INSTITUTE, with the co-operation and endorsement of the Committee on Instruction, have spared no efforts to maintain the high character for which the lectures of the past few years have been notable.

DRAWING SCHOOL.

The Drawing School has shown considerable increase over the attendance of the previous year, and its efficient management, together with the marked interest of the students in their work, gives the assurance that this valuable adjunct to the INSTITUTE will continue to be successful.

The attendance for the Spring Term of this year was, ...	192
And for the Fall Term, ...	224
	416
Making an increase over the previous year of, ...	44

COMMITTEE ON SCIENCE AND THE ARTS.

The impending changes in the constitution of the Committee which were noted in last year's report, the most noteworthy of which was the making of the Committee an elected body with a fixed number of members (forty-five), in place of the voluntary association of former years, went into effect in January of the past year.

The reorganized Committee included in its membership a number of the most capable and active members of the INSTITUTE, and the Board feels warranted in congratulating the INSTITUTE on a change which gives promise of greatly increasing the usefulness of this Committee.

During the year, the Committee considered seventeen new applications and reported upon nine, and has nine cases under consideration at the present time. In two of these cases the Committee awarded Certificates of Merit; in one case the Elliot Cresson Medal, and in two cases recommended the award of the John Scott Legacy Premium and Medal.

REORGANIZATION AND FUTURE WORK.

The Committee on Reorganization having completed the revision of the By-Laws, and provided for the creation of a Board of Trustees, it remains that these Trustees be elected—a proceeding that it would be advisable the Board of Managers should carry out as soon as practicable.

It is within the province of this Committee on Reorganization to continue its work in the matter of formulating and reporting "what should be the future work of the INSTITUTE," and also to prepare plans for a suitable building in which the INSTITUTE can carry out that work, and it is of the utmost importance that the Committee should continue its labors to a conclusion.

The wants of the INSTITUTE are vital. It is a great and noble institution, worthy of the name it bears, and doing invaluable work for the City of Philadelphia and for the world.

Yet it is embarrassed in every direction; for want of room in its building, want of conveniences in its educational departments, and, above all, want of funds. Every year its accounts present a deficiency. This cannot go on forever. Unless some change takes place for the better, the day will surely arrive, although it is hoped it may be far off, when its doors will be closed. Cannot those who are interested in the promotion of educational privileges, and who have the means to make a practical application of their interest, have their eyes opened to the field here presented?

Under the reorganization, the system of the INSTITUTE is in the best shape possible for such aid. Its Managers, its Officers and its Professors are active, reliable, energetic and economical, doing all they can with the least possible expenditure; but, it may as well be plainly spoken, it is money that is wanted, money, properly and securely vested in the hands of its Trustees, the income to be rightly applied to the continuance and advancement of the INSTITUTE. From an examination of the expenditure account it will be evident to anyone that a decrease in these expenditures cannot readily be made without seriously crippling the efficiency of the INSTITUTE.

New and more extensive buildings are needed. The Library has far outgrown its quarters. Here is one of the most valuable purely scientific libraries of the country, proving its usefulness for consultation and reference every day, containing many volumes that, if destroyed, could never be replaced, and yet in a building not even fire-proof.

Cannot a systematic effort be made to improve this state of things? The INSTITUTE asks for aid. Shall its appeal be in vain?

By Order of the Board, JOS. M. WILSON, *President.*

The Committee on Library made the following report:

THE COMMITTEE ON THE LIBRARY respectfully report, that during the year 1887 there have been added to the Library:

Volumes, bound,	2,099
Volumes, unbound,	448
Pamphlets,	1,120
Total,	3,677
Maps and charts,	108

The above is exclusive of duplicates, of which a large number were acquired during the year, as follows:

Volumes, bound,	618
Volumes, unbound,	90
Pamphlets,	863
Total,	1,571

TOTAL NUMBER OF VOLUMES IN THE LIBRARY. Taking the statement of the Librarian at the close of the year 1886, as, ... 27,998 volumes,
and adding the additions of 1887, ... 3,667 "
We have a total of . . . . . 31,665 "

which is exclusive of a pamphlet collection of about 8,000, classified, catalogued and accessible for reference.

THE B. H. MOORE FUND.—There have been purchased during the year from the income of this fund 317 volumes, and one pamphlet and chart, at an expenditure of $424.96, leaving an unexpended balance of $75.04.

DUPLICATES.—During the past year duplicates have been disposed of to the value of, ... $174.89
And books received in exchange to the value of, ... 141.10
Leaving to the credit of the account, ... $33.79

SERIALS.—During the year the following important ones were completed:

The American Gas Light Journal.
"Proceedings of the American Gas Light Association."
"Proceedings of the Society for Psychical Research."
"Transactions of the American Institute of Electrical Engineers."

Through the liberality of the members and friends of the INSTITUTE, the sum of $1,135 has been subscribed and deposited with the Treasurer to be applied to the completion of the more important serials in the library. The committee has been in correspondence with book dealers in Europe, and has now the invoices of the first shipment, amounting to about $600, towards the furtherance of this important work.

GOVERNMENT PUBLICATIONS.—By the courtesy of the Moyamensing Literary Institute, of this city, there have been transferred to the Library of the FRANKLIN INSTITUTE the Government publications deposited with that institution, amounting to 1,629 volumes. Having relinquished in favor of the FRANKLIN INSTITUTE the designation as a public depository, the Hon. Sam'l J. Randall has directed the transfer to be made in the Department at Washington. The annual addition to the library from this source will be voluminous, and added to the collection of former years, will form a valuable library of Government publications, freely accessible to the public.

WANT OF ROOM AND PROPER PROTECTION for the most important library of scientific and technical publications in the United States continues to be a source of solicitude to your committee. The time has now arrived when the question will have to be considered, whether to check the increase of the library to accommodate it to its restricted quarters, or to provide a suitable building for its expansion and preservation, which shall afford ample space for its natural increase, and comfort and convenience to the members of the INSTITUTE and to the public, to whom the Library is accessible.

CHAS. BULLOCK,
Chairman of Committee on Library.

The Chemical and Electrical Sections likewise presented detailed reports of their operations during the year 1887.

The foregoing reports were severally accepted.

MR. W. U. WOODRUFF, of Hartford, described the advantages of a new system of keying for machinery, which he had devised and proposed as a standard, and illustrated the subject by the exhibition of a complete set of cutters and keys. The subject of Mr. Woodruff's communication has been referred to the Committee on Science and the Arts, for an investigation and report thereon.

PROF. EDWIN J. HOUSTON made an oral communication on the "Paillard Non-Magnetizable Watch," giving an account of a series of tests to which he had subjected it, and which fully confirmed the claims of the inventor.

The SECRETARY read his annual report, which appears elsewhere in the JOURNAL.

The following preamble and resolution were unanimously adopted, on the motion of PROF. LEWIS M. HAUPT, viz.:

WHEREAS, During this first century of our national existence, the public civil works conducted by the various departments of the General Government, have reached such magnitude and importance as to require a greater economy and efficiency of administration; and,

WHEREAS, The present promiscuous assignment of technical bureaus to departments for which they have no affinity; the reduplication of services; the frequent changes in the *personnel;* the failure in passing the appropriation bills and resulting disorganization of the employés, and the absence of personal responsibility, are not conducive to such economy and efficiency; and

WHEREAS, The FRANKLIN INSTITUTE of the State of Pennsylvania, for the promotion of the Mechanic Arts, has ever maintained a deep interest in the development of the mechanical and civil industries of our country, and desires to encourage and promote a more systematic organization of these important bureaus on the part of the General Government; therefore,

Resolved, That the FRANKLIN INSTITUTE respectfully but urgently requests the members of the Fiftieth Congress of the United States to enact such laws as will result in a more efficient and systematic organization of the numerous technical bureaus and greater economy of administration in the conduct of the Public Civil Works of the Government.

The result of the annual election for officers, managers and members of the Committee on Science and the Arts is given below:

President (to serve one year), ... JOSEPH M. WILSON.
Vice-President (to serve three years), ... W. P. TATHAM.
Secretary (to serve one year), ... WM. H. WAHL.
Treasurer (to serve one year), ... SAMUEL SARTAIN.

Managers (to serve three years): Hugo Bilgram, Cyrus Chambers, Jr., G. Morgan Eldridge, Henry R. Heyl, Chas. Hare Hutchinson, Samuel R. Marshall, Chas. E. Ronaldson, William Sellers.

Auditor (to serve three years), Lewis S. Ware.

Members of the Committee on Science and the Arts (to serve three years): J. M. Emanuel, Prof. L. B. Hall, John Haug, Henry R. Heyl, C. W. Howard, Fred. E. Ives, W. M. McAllister, H. Pemberton, Jr., Philip Pistor, Prof. S. P. Sadtler, T. C. Search, Thomas Shaw, Louis H. Spellier, W. Rodman Wharton, Moses G. Wilder.

Adjourned.

WM. H. WAHL, *Secretary.*

LIST OF BOOKS

PRESENTED TO THE LIBRARY.

(*Continued.*)

Massachusetts. Annual Reports of the Commissioner of Insurance for 1885. Part 2. Life, etc. Boston. Presented by the Commissioner.

Massachusetts. Board of Commissioners of Savings Banks. Annual Reports for 1876 and 1882. Boston, 1877 and 1883. Presented by the State Librarian.

Massachusetts. Census of 1875. Vols. 1 to 3. Boston, 1876–77. Presented by the State Librarian.

Massachusetts. First Annual Report of the State Agricultural Experiment Station at Amherst. 1883. Boston, 1884. Presented by the Director.

Massachusetts. Forty-third Report Relating to the Registry and Return of Births, Marriages and Deaths in the Commonwealth for 1884. Boston, 1885. Presented by the Secretary of State.

Massachusetts. History of Wages and Prices. 1752–1883. By E. D. Wright, Chief of Bureau of Statistics of Labor. Boston, 1885. Presented by the Chief of Bureau.

Massachusetts. Manual for the Use of the General Court. Boston, 1685. Presented by the State Librarian.

Massachusetts. Registry and Return of Births, Marriages and Deaths, etc. Second; Fourth to Sixth; Eighth to Fourteenth; Seventeenth, Eighteenth, Twenty-ninth and Thirty-third. Annual Reports. Boston. Presented by the State Librarian.

Massachusetts. Report of a Commission Appointed to Consider a General System of Drainage for the Valleys of Mystic, Blackstone, and Charles Rivers. Boston. Wright & Potter Printing Company. 1886. Presented by the Chief Engineer.

Massachusetts. State Agricultural Experiment Station. Bulletins Nos. 16, 17 and 19. 1885–6.

Massachusetts. State Agricultural Experiment Station. Second Annual Report. 1884. Amherst, 1885. Presented by the Director.

Massachusetts State Board of Health, Lunacy and Charity. Sixth and Seventh Annual Reports. Boston. Wright & Potter Printing Company. 1885–86. Presented by the Board.

Massachusetts State Library. Annual Report of the State Librarian for 1885. Presented by the State Library.

Massachusetts. Statistical Information Relating to Certain Branches of Industry, 1855 and 1865. Boston, 1856 and 1866. Presented by the State Librarian.

Master Car-Builders' Association. Reports of Proceedings of Eighth, Ninth, Eleventh to Fifteenth, and Seventeenth and Eighteenth Annual Conventions. New York, 1874–84. Presented by M. N. Forney, Secretary.

Matteucci Carlo. Living Beings. Philadelphia, 1848.
Presented by Mrs. Wm. B. Rogers.

Maury, M. F. Physical Geography of the Sea. Second Edition. Enlarged and Improved. New York, 1855. Presented by Mrs. Wm. B. Rogers.

Mayor of Philadelphia. Annual Report of Wm. B. Smith, for 1884.
Presented by his Honor, the Mayor.

Memorial Record of the Fathers of Wisconsin. Madison, 1880.
Presented by the State Historical Society.

Memphis and Charleston Railroad Company. Twenty-ninth and Thirtieth Annual Reports of Directors for 1883–84. Presented by the Company.

Mendenhall, Geo. The Medical Students' Vade Mecum. Philadelphia, 1847.
Presented by Mrs. Wm. B. Rogers.

Mérat, F. V. et A. J. De Lens. Dictionnaire Universelle de Matière Médicale, et de Therapeutique Générale. Paris, 1829–34.
Presented by Mrs. Wm. B. Rogers.

Meriden. City of. Revised and Amended Charter and By-Laws. 1882.
Presented by the Mayor.

Merriman, M. Mechanics of Materials. N. Y., 1: 1885.
Presented by John Wiley & Sons.

Meteorological Committee of the Royal Society. Annual Report for 1885. London, 1886. Presented by the Society.

Meteorological Council. Royal Society. Contributions to our Knowledge of the Meteorology of the Arctic Regions. Part 4. Vol. 1. London, 1885.
Presented by the Royal Society.

Meteorological Council. Royal Society. London. Hourly Readings. January to March, 1883, and April to June, 1885.
Presented by the Council.

Meteorological Council. Royal Society. Monthly Weather Report for March, April and May, August to December, 1885. London, 1885.
Presented by the Council.

Meteorological Council. Royal Society. Official No. 66. Meteorological Observations at Stations of the Second Order for 1881. London, 1886.
Presented by the Council.

Meteorological Council. Royal Society. London. Quarterly Weather Report of the Meteorological Office, July to December, 1877; January to March, 1886. Presented by the Council.

Meteorological Council of the Royal Society. Weekly Reports from April to September and December, 1885. April 19th to July 5, 1886.
Presented by the Council.

Meteorological Department. Government of India. Indian Meteorological Memoirs. Vol. 3, Part 1; and Vol. 4, Part 1.
Presented by the Department.

Meteorological Observations Recorded at Six Stations in India. February and March, June to August and December, 1885, to February, 1886.
Presented by the Department.

Meteorological Observations. India. Registers of Original Observations in 1885. Reduced and corrected. January, 1885.
Presented by the Meteorological Department.

Mialke. Chimie. Paris, 1856. Presented by Mrs. Wm. B. Rogers.

Michigan. Annual Report of the Board of State Auditors for the State of Michigan for the Year 1883. Lansing, 1884.
Presented by the Secretary of State.

Michigan. Annual Reports of the Bureau of Labor and Industrial Statistics. February 1, 1884–85. Lansing.
Presented by the Secretary of State.

Michigan. Annual Reports of the Commissioner of Mineral Statistics for 1880–82 and 1884. Marquette & Lansing, 1880–84.
Presented by His Excellency the Governor of the State, R. A. Alger.

Michigan. Annual Reports of the Commissioner of Railroads for 1875, 1878, 1880, 1883 and 1884. Lansing. Presented by the Commissioner.

Michigan. Annual Report of the Commissioner of the State Land Office for the Fiscal Year Ending September 30, 1884. Lansing, 1885.
Presented by the Secretary of State.

Michigan. Board of State Commissioners for the General Supervision of Charitable, etc., Institutions. Second, Third, Fifth, Sixth, and Abstract from Seventh Biennial; and Annual Reports for 1874, 1876, 1879–80, 1881–82, 1885–86. Lansing. Presented by the Secretary of State.

Michigan Board of State Commissioners for the General Supervision of Charitable, Penal, etc., Institutions. Report and Special Report. Lansing, 1873 and 1872.

Michigan. Fish and Game Laws. Lansing, 1881.

Michigan. First to Sixth Annual Reports of Secretary of State on Farms and Farm Products, 1878–9, 1883–4. Lansing, 1880–84.

Michigan. General Railroad Laws, and Digest of Decisions of the Supreme Court, 1881. Lansing. Presented by the Secretary of State.

Michigan. Geological Survey. Reports. Vols. 1 to 4, and Atlas. New York, 1873–81. Presented by the State Library.

Michigan. Joint Documents of the State Containing the Annual Reports of the Heads of Various State Departments, 1858–83. Lansing, 1859–84.

Michigan. Laws Relating to the Incorporation of Manufacturing Companies. Lansing. Presented by the Secretary of State.

Michigan. Proceedings and Addresses at Sanitary Convention, held March 19 and 20, 1885. Lansing, 1885.
Presented by the State Board of Health.

Michigan. School for the Blind. Second Biennial report of the Board of Commissioners. Lansing, 1885.

Michigan. Seventeenth Annual Report relating to the registry and return of Births, Marriages and Deaths for the year 1883. Lansing, 1885. And extracts from the reports of the Board of Health.
Presented by the Secretary of State.

Michigan. State Agricultural College. Catalogues of Officers and Students. Twenty-eighth year. 1884–85. Presented by the President.

Michigan. State Board of Agriculture. Twenty-third Annual Report of the Secretary from October 1, 1883, to September 30, 1884. Lansing, 1884. Presented by the Secretary.

Michigan. State Board of Corrections and Charities. Seventh Biennial Report, 1883–84. Lansing, 1885.

Presented by the Secretary of State.

Michigan. State Board of Health. Twelfth Annual Report of the Secretary for 1884. Lansing, 1885. Presented by the Secretary.

Michigan. State Horticultural Society. Annual reports of the Secretary for 1881–84. Lansing, 1882–85.

Michigan. State Mining Law of 1877. Lansing, 1881.

Michigan. State Pomological Society. Annual Reports for 1872–75–76 to 1880. Lansing, 1873–81.

Michigan. State Prison. Annual Report of the Inspectors and Officers for the year closing September 30, 1884. Lansing, 1884.

Michigan. The General School Laws, with Appendices. 1881. Lansing.

Michigan. The Liquor Laws of the State. Lansing, 1881.

Presented by the Secretary of State.

Milano. Atti del Collegio degli Ingegneri ed Architetti in. May–September, 1885. Three parts. Presented by the Society.

Milwaukee Board of Public Works. Annual Reports for 1883–1885. Milwaukee, 1886. Presented by G. H. Benzenberg, City Engineer.

Milwaukee, Wis. Annual Reports of the City Comptroller, containing the Reports of the Water Department and Board of Public Works. 1873, 1874, 1876, 1877, 1878, 1882 and 1883. Presented by the Comptroller.

Mineral Products of the United States. Calendar Years 1882 to 1884. By Albert Williams, Jr. Presented by the U. S. Geological Survey.

Mineral Waters. By A. C. Peale. U. S. Geological Survey. Washington, 1885. Presented by the Survey.

Mining Exhibition, under the Auspices of the Mining Institute of Scotland, held 1st till 24th September, 1885. Official Catalogue of Exhibits. Hamilton, 1885.

Mining Institute of Scotland. Report Relative to the Mining Exhibition in Glasgow. September, 1885.

Mining Institute of Scotland. Transactions. Vols. 1 to 6 inclusive, complete; and Nos. 1 to 3 of Vol. 7. Hamilton, 1879 to 1885.

Presented by the Institute.

Minnesota. Geological and Natural History Survey. Thirteenth Annual Report, 1884. St. Paul, 1885.

Minnesota. Geology of Minnesota. Final Report. Vol. 1, 1872–82. Minneapolis, 1884. Presented by H. H. Winchell, State Geologist.

Mitscherlica, E. Elemens de Chimie. Bruxelles, 1835 and 6. Three Vols.

Presented by Mrs. Wm. B. Rogers.

Mobile, Ala. Monthly Statements of Mortality for January–August, 1885. Presented by the Board of Health.

Monaco. Annuaire de la Principanté de. 1878. Monaco, 1878.

Presented by L. S. Ware.

Montreal Water Works. Annual Reports of the Superintendent for Years ending January, 1863 and 1875. Presented by the Superintendent.

Moorman, J. J. Mineral Springs. Philadelphia, 1873.

Morris, D. Class-Book of Inorganic Chemistry. London, 1870.

Mülder, G. J. The Chemistry of Vegetable and Animal Physiology. Edinburgh, 1849.

Mülder, G. J. Chemistry of Vegetable and Animal Physiology. Part 1. London: N. D.

Murphy, John G. Chemistry. Philadelphia, 1851.

Murray, John. Elements of Chemistry. 2 Vols, 4th Ed. Edinburgh, 1817.

Murray, John. System of Chemistry. In 4 Vols. Vols. 3 and 4. 4th Ed. Edinburgh, 1819. Presented by Mrs. Wm. B. Rogers.

Musée Teyler. Archives. Ser. 2. Vol. 2. 3me Partie. 1885.

Catalogues de la Bibliothèque. Par E. C. Kama. 1885.
Presented by the Museum.

Napier, Jas. A Manual of Electro-Metallurgy. London, 1852.

Naguet, A. Legal Chemistry. New York, 1876.

National Academy of Sciences. Report of Operations for 1863. Washington, 1864. Presented by Mrs. Wm. B. Rogers.

National Almanac and Annual Record for the year 1863. Philadelphia.
Presented by A. Whitney & Sons.

National Board of Health. Annual Reports for 1880, 1881, 1882, 1884 and 1885. Washington. Presented by the Board.

Natural Gas. How to get it and how to use it as fuel. Philadelphia Company. Presented by the Company.

Naval, Scientific and Professional Papers. Nos. 8, 9, 15, 18 and 20. Washington, 1882–1886.
Presented by the Bureau of Navigation, Navy Department.

Naval Observatory, U. S. Astronomical and Meteorological Observations made in 1882. Washington, 1883. Presented by the Observatory.

Naval Operations. Papers on. Washington, 1885.
Presented by the Hydrographic Office, U. S. Navy.

Navy Department, U. S. Annual Reports of the Secretary for 1884 and 1885. Washington. Presented by the Secretary of the Navy.

Navy, U. S. Regulations governing uniforms of officers and men. Washington, 1886. Presented by the Department.

Nesbit, A. Treatise on practical Mensuration. York, 1835.
Presented by Mrs. Wm. B. Rogers.

Nevada. Appendix to Journals of Senate and Assembly of Twelfth Session of Legislature of the State of Nevada. Carson City, 1885.
Presented by the State Library.

Newark, N. J. Board of Health. First Annual Report for 1885.
Presented by the Board.

New Bedford, Mass. Board of Health. Annual Report for 1885.
Presented by the Board.

New Bedford Water Board. Sixteenth Annual Report for 1885.
Presented by the Board.

Nebraska. State Historical Society. Transactions and Reports. Vol. 1. 1885. Presented by the Society.

New Brunswick Water Commissioner. Annual Report for 1885. Presented by A. J. Jones, Superintendent.

New Hampshire. Annual Reports of the State Officers. 1885. Presented by the State Librarian.

New Hampshire. State Board of Health. Annual Report for 1884-85. Concord. Presented by the Board.

New Haven, Conn. Board of Health. Annual Reports of the Board for 1885. Presented by the Board.

New Haven, Conn. Monthly Statement of Mortality from March, 1877, to August, 1885. Issued by the Board of Health. Presented by the Board.

New Jersey. Annual Reports of the Commissioners of Fisheries for 1873 to 1883. Trenton.

New Jersey. Annual Reports of the Comptroller of Currency for 1872--1884. Trenton.

New Jersey. Annual Reports of the Railroad and Canal Companies, for 1866, 1871, 1872, 1874 to 1883. Trenton.

New Jersey. Annual Statements of the Banks and Savings Institutions for 1881, 1882 and 1885. Trenton.

New Jersey. Annual Report of the Commissioner of Railroad Taxation for 1883. Toms River, N. J. Presented by His Excellency, the Governor.

New Jersey Archives. First Series. Vol. 9. Newark, 1885. Presented by New Jersey State Historical Society.

New Jersey Board of Health. Ninth Annual Report. Trenton, 1885. Presented by the State Board.

New Jersey. Documents relating to the Colonial History of the State. Vol. 10. Newark, 1886. Presented by the State Historical Society.

New Jersey. Geological Survey. Annual Report for 1885. Trenton.

New Jersey. Geological Survey. Brachiopoda, etc., of the Raritan Clays and Greensand Marls of New Jersey. By R. P. Whitfield. Trenton, 1886. Presented by the State Geologist.

New Jersey Historical Society. Proceedings. Second Series. No. 4. Vol. 8. Nos. 1 and 2. Vol. 9. 1886. Presented by the Society.

New Jersey. Report of the Oyster Commission. Created by an Act of the Legislature, approved, March 23, 1883. Camden, 1884.

New Jersey. Report of the Special Joint Committee on Taxation of the Property of Railroad and other Corporations. Camden, 1884. Presented by His Excellency, the Governor.

New Jersey State Board of Agriculture. Ninth, Eleventh and Twelfth Annual Reports for 1881, 1883 and 1884. Trenton, 1882-85. Presented by the Board.

New London. Fourteenth Annual Report of the Board of Water Commissioners. September, 1885. Presented by the Board.

New Mexico. Compiled Laws. Approved, 1884. Santa Fé, 1885. Presented by the Governor.

New Orleans Water Works Company. First to Eighth Annual Reports. 1879–1886. Presented by the Company.

New South Wales. Annual Reports of the Minister of Public Instruction upon the Condition of the Public Schools for 1880 to 1884. Sydney, N. S. W., 1881–1885. Presented by the Minister.

New System of Chemistry. Comprehending the latest Discoveries and Improvements. Philadelphia, 1800. Presented by Mrs. Wm. B. Rogers.

Newton Machine Tool Works. Album. Presented by C. C. Newton.

Newton, Mass. Annual Report of the Overseer of the Poor, together with the Report of the Agent of the Board of Health for the year ending December 31, 1884. Presented by Nathan Mosman.

New York. Canal Department of State. Annual Report of the Auditor on Tolls. Albany, 1850.

New York State Engineer and Surveyor. Annual Report on Railroads for 1853. Albany, 1854. Presented by A. Whitney & Sons.

New York, State of. Annual Report of the Superintendent of Public Works for 1883 and 1884. Albany, 1884–1885. Presented by the Superintendent.

New York State Pharmaceutical Association. First to Eighth Annual Reports. Presented by the Association.

New Zealand. Nineteenth Annual Report of the Colonial Museum and Geological Survey. 1885. Presented by the Museum.

New Zealand Institute. Transactions and Proceedings. Vol. 17 and 18, and Index to Vols. 1 to 17. Wellington, 1885 and 1886. Presented by the Institute.

Nichol, J. P. Architecture of the Heavens. Ninth Edition. London, 1851. Presented by Mrs. Wm. B. Rogers.

Niles Tool Works. Album of Machine Tools. Presented by Niles Tool Works.

Nineteenth Century Almanac. Philadelphia, 1885. Presented by Hanson Brothers.

North Carolina Agricultural Experiment Station. Annual Report for 1884 and 1885. Presented by Charles W. Dabney, Jr.

Northern Central Railway Company. First to Thirtieth Annual Reports of the President and Directors. 1855 to 1884. Presented by the Company.

Northern Wisconsin Agricultural and Mechanical Association. Transactions. Vols. 4–6 and 9 and 10. 1876–7–1883. Madison, 1877–1884. Presented by the State Historical Society.

Nugent, Thos. A New Pocket Dictionary of the French and English Languages. Philadelphia, N. D. Presented by Mrs. Wm. B. Rogers.

Oersted, Hans Christian. The Soul in Nature. London, 1852. Presented by Mrs. Wm. B. Rogers.

Official Army Register for January, 1886. Washington. Presented by the Adjutant General's Office.

Official Register of the United States, containing a list of Officers and Employés of the Government to July 1, 1885. Washington, 1886. Presented by the Hon. Wm. D. Kelley.

Ohio Agricultural Experiment Station. Fourth Annual Report, 1885. Columbus, 1886. Presented by the Director.

Ollendorff, H. G. New Method of Learning the German Language. London, 1838. Presented by Mrs. Wm. B. Rogers.

Ordnance and War Ships. Report of the Select Committee of the Senate, with an appendix. Washington, 1886. Presented by Prof. Soley, Librarian Navy Department Library.

Ordnance Office, War Department, U. S. Annual Reports of the Chief, for Year ending June 30, 1885. Presented by Chief of Ordnance.

Osborn, F. C. Tables of Moments of Inertia and Squares of Radii of Gyration. Cleveland, 1886. Presented by the Author.

Otto, Fr. Jul. A Manual of the Detection of Poisons by Medico-Chemical Analysis. New York, 1857.

Page, David. Life of the Globe. Edinburgh, 1861.

Paley, William. Natural Theology. Hallowell, 1826.

Parchappe, Dr. Max. Galilée; sa Vie, ses Decouvertes et ses Travaux. Paris, 1866.

Parnell, E. A. Applied Chemistry. London, 1844.

Parsons, Theo. Laws of Business for all the States of the Union. Hartford, 1869. Presented by Mrs. Wm. B. Rogers.

Patents. India, Ceylon, etc. Information and Forms. By H. H. Remfry. Calcutta, 1885.

Patents. India, Ceylon, Straits Settlements and Hong-Kong. Information and Forms. Calcutta, 1885. Presented by H. H. Remfry.

Patent Law Practice and Forms of Hawaii. New York, 1885. Presented by Richards & Co.

Patent Office. British. Abridgements Relating to the Preparation of India-Rubber and Gutta-Percha. 1867–1876. London, 1885. Presented by the Commissioners of Patents.

Patent Office. British. Reports of Patent and other Cases. Vols. 1–3, 1884–1886. Presented by the Commissioners of Patents.

Patent Office. British. Specifications and Drawings. Vols. 1–86. London, 1884. Abridgements of Specifications Relating to Preparing, etc., Cork. Part 3, 1877–1883. London, 1885. Eight Amended Specifications, etc.

Patent Office. British. The Official Journal, March 17 to June 30, 1885. London.

Patent Office. British. Illustrated Journal of Patented Inventions. March 20 to June 26, 1885. London. Presented by the Commissioners of Patents.

Patent Office. United States. Alphabetical Lists of Patentees and Inventions for Quarter ending March 31, 1885.

Patent Office. United States. Annual Report of the Commissioner for 1884 and Index to the Gazette. Washington, 1885.

Patent Office. United States. Specifications and Drawings for April, 1884, to July, 1886. Washington, 1884–1886. Presented by the Commissioner.

Patents. Victoria. Patents and Patentees. Indices for the years 1875 to 1880. Melbourne. Presented by the Registrar General.

Peabody Museum of American Archæology and Ethnology. Eighteenth and Nineteenth Annual Reports. Vol. 3, Nos. 5 and 6. Cambridge, 1886. Presented by the Museum.

Peintures et Sculptures. Acquises par l'Etat au Salon de 1885. Paris. Presented by L. S. Ware.

Pennsylvania. Annual Reports of the Inspectors of Mines for 1880, 1883 and 1884. Harrisburg. Presented by the Librarian of the Senate.

Pennsylvania. Annual Report of Secretary of Internal Affairs. Part 4. Railroads, Canals, etc., for 1884. Harrisburg, 1885. Presented by the Secretary.

Pennsylvania Canal Company. Eighteenth and Nineteenth Annual Reports for the years 1884 and 1885. Presented by the Company.

Pennsylvania. Department of Internal Affairs. Annual Reports of Secretary. 1885–86. Harrisburg, 1886. Presented by the Secretary.

Pennsylvania. Executive Documents. 1879–80, Parts 1 and 2; 1880–81, Parts 1 and 2; 1881–82, Part 2; 1882–83, Parts 1 and 2; 1883–84, Parts 1 and 2; 1884–85. Harrisburg, 1879–85. Presented by Capt. J. C. Delaney, Librarian of the Senate, Harrisburg.

Pennsylvania Horticultural Society. Programme for 1885; Schedule of Premiums, 1885; Act of Incorporation and By-Laws. Philadelphia, 1885. Presented by the Society.

Pennsylvania Institution for the Blind. Second, Thirty-second to Thirty-fourth, Thirty-seventh to Forty-first, Forty-third to Forty-eighth, Fiftieth to Fifty-second Annual Reports of the Managers. Philadelphia, 1835–1884. Presented by the Managers.

Pennsylvania. Laws of 1867, 1869, 1871 to 1873, 1877 to 1879, 1881, 1883 and 1885. Harrisburg. Presented by the Secretary of the Commonwealth.

Pennsylvania Railroad. Annual Report of the Board of Directors for 1885. Philadelphia. Presented by the Secretary of the Company.

Pennsylvania Railroad Company. List of Stations and Agents. February 1, 1885. Philadelphia. Presented by the Company.

Pennsylvania State College. Annual Report. 1883. Presented by the President.

Pennsylvania. Second Geological Survey. Reports of Progress. A. A. Atlas Northern Anthracite Field. Part 1; F2; K4; R. R. Part 2 and X. Harrisburg. Presented by the Commissioners.

Pennsylvania State College. Report of Committee appointed to Investigate the Affairs of the Pennsylvania State College. Harrisburg, 1883. Presented by the Secretary of Internal Affairs.

Pennsylvania State College. Circular. 1884–5. Agricultural Bulletin No. 11. Presented by the President.

Pharmacopœia of the United States of America. Philadelphia, 1880. Presented by Mrs. Wm. B. Rogers.

Philadelphia Board of Trade. Fifty-third Annual Report. 1885. Philadelphia, 1886. Presented by the Board.

Philadelphia Board of Trade. Forty-fifth Annual Report, by G. L. Buzby, Secretary. Philadelphia, 1878. Presented by A. Whitney & Sons.

Philadelphia and Reading Railroad Company. Report of the Receivers for the year 1885. Presented by the Company.

Philadelphia. Annual Report of the Chief Commissioner of Highways for 1884. Philadelphia, 1885. Presented by the Commissioner.

Philadelphia College of Pharmacy. Sixty-sixth Annual Announcement. Philadelphia, 1886. Presented by the College.

Philadelphia. Health Officer's Annual Report of Births, Marriages and Deaths for 1884. Presented by the Health Office.

Philadelphia Maritime Exchange. Annual Reports. Philadelphia, 1878–82 and 1884–85. Presented by the Secretary.

Philadelphia *Record* Almanac, 1886. Presented by the Publisher.

Philadelphia Water Department. Annual Report for 1884. Presented by Col. Wm. Ludlow, Chief Engineer.

Phillips, J. A. Manual of Metallurgy. London, 1852. Presented by Mrs. Wm. B. Rogers.

Philosophical Society of Glasgow. Proceedings. Vol. 16. Glasgow, 1885. Presented by the Society.

Philosophical Society of Washington. Bulletin. Vol. 8. Washington, 1885. Presented by the Society.

Phœnix Bridge Company. Album of Designs. Philadelphia. J. B. Lippincott & Co., 1885. Presented by the Company.

Photography. Abridgements of Specifications Relating to. A. D. 1877–1883. Part 3a. London, 1885. Presented by the Commissioners.

Physicians' Visiting List for 1886. Philadelphia, 1885. Presented by P. Blakiston, Son & Co., Publishers.

Pickering, E. C. Atmospheric Refraction. Cambridge, 1886. Presented by the Author.

Pickering, E. C. Plan for the Extension of Astronomical Research. Cambridge, 1886. Presented by the Author.

Pickering, Wm. H. Methods of Determining the Speed of Photographic Exposers. Principles involved in the Construction of Photographic Exposers. Cambridge, 1885. Presented by the Author.

Pickering, Wm. H. Photography of the Infra-Red Region of the Solar Spectrum. 1884. Presented by the Author.

Pinner, Adolph. An Introduction to Study of Organic Chemistry. New York, 1883. Presented by Mrs. Wm. B. Rogers.

Pittsburgh, Cincinnati and St. Louis Railway Company. Seventeenth Annual Report. 1884. Philadelphia, 1885. Presented by the Company.

Polar Question, The. By Lieut. J. W. Danenhower. Presented by the Author.

Poor, H. V. Manual of the Railroads of the United States for 1875–76 and 1880. New York. Presented by H. V. and H. W. Poor.

Pope, F. L. Electric Telegraph. New York, 1871. Presented by Mrs. Wm. B. Rogers.

Porter-Allen Engines. Descriptive Catalogue. Philadelphia. Presented by the Southwark Foundry.

Postal Microscopical Society. Journal. Vols. 1–2. Alfred Allen, Editor. London, 1882–83. Presented by the Editor.

Precious Metals in the United States. Report of the Director of the Mint upon, during 1884. Washington, 1885. Presented by the Director.

Precious Metals. Statistics and Technology of. (Vol. 13 of Tenth Census.) Prepared by S. F. Emmonds and G. F. Becker. Washington, Government, 1885. Presented by the Department of the Interior.

Prescott, A. B. Outlines of Proximate Organic Analysis. New York, 1875.

Proctor, R. A. The Sun. London. Longmans et al. 1871.

Prolix, P. Letters Descriptive of the Virginia Springs. Philadelphia, 1837. Presented by Mrs. Wm. B. Rogers.

Providence, R. I. Annual Reports of the City Engineer for 1880–84. Providence. 1881–85.

Providence, R. I. Annual Reports Upon the Births, Marriages and Deaths in the City, 2d to 20th and 21st to 30th. Providence, 1857 to 1885.

Providence, R. I. Quarterly Reports of the Board of Public Works, 1st to 10th. Providence, 1883–85. Presented by his Honor, the Mayor.

Provincial Board of Health, Ontario. Report on the Quarantine System of the St. Lawrence. Toronto, 1886. Presented by the Board.

Public Ledger Almanac, 1886. Philadelphia. Presented by Geo. W. Childs.

Public Library of Cincinnati. Bulletin for 1885. Cincinnati, 1886. Presented by the Librarian.

Quain, Jones. Human Anatomy. In two Vols. Vol. 2. Philadelphia, 1849. Presented by Mrs. Wm. B. Rogers.

Quincy, Ill. Annual Report of the Board of Health for 1885. Presented by the Board.

Railroad, Canal and County Map of Pennsylvania, New Jersey, etc. Philadelphia. Barnes. 1864.

Rankine, Wm. J. M. Useful Rules and Tables. London, 1866. Presented by Mrs. Wm. B. Rogers.

Reading, Pa. Annual Reports of the Board of Health for 1874 to 1885. Presented by the Secretary of the Board.

Reese, John J. A Manual of Toxicology. Philadelphia, 1874. Presented by Mrs. Wm. B. Rogers.

Register of the Commissioned, etc., Officers of the Navy of the United States for 1886. Washington. Presented by the Secretary of the Navy.

Regnault, M. V. Elements of Chemistry. Two Vols. Philadelphia, 1856.

Reid, D. B. Elements of Chemistry. Edinburgh, 1839. Presented by Mrs. Wm. B. Rogers.

Rhode Island. State Board of Health. Second Annual Report for 1879, 1882 to 1884. Providence, 1880 to 1885. Presented by the Secretary.

Rhode Island. Thirtieth to Thirty-seventh Reports upon the Births, Marriages and Deaths. Providence, 1878--1883. Presented by the Secretary of the Board of Health.

Riant, A. Le Café, le Chocolat, le Thé. 3d Ed. Paris, 1880. Presented by L. S. Ware.

Richmond, Ind. Annual Report of the Board of Health for 1883 to 1885. Presented by the Health Officer.

Richmond, Va. Annual Reports of the Board of Health. 1874, 1876, 1877, 1879, 1880, 1882, 1883, 1884. Presented by the Board.

Ritch, Wm. G. History, Resources and Attractions of New Mexico. Sixth Ed. Boston, 1885. Presented by the Secretary of the Territory.

Robert, H. M. Pocket Manual of Rules of Order. Chicago. Griggs & Co. 1885. Presented by the Author.

Roberts, John B. Compend of Anatomy. Philadelphia, 1881.

Roberts, John B. The Pericardium. Philadelphia, 1880. Presented by Mrs. Wm. B. Rogers.

Roper, S. Use and Abuse of the Steam Boiler. Philadelphia, 1876. Presented by Dr. Wm. H. Wahl.

Rose, H. Manual of Analytical Chemistry. London, 1831.

Rose, H. Practical Treatise on Chemical Analysis, with notes and additions. By A. Normandy. London, 1848.

Rossiter, W. Physics. Edinburgh, 1871. Presented by Mrs. Wm. B. Rogers.

Royal Cornwall Polytechnic Society. Fifty-second and Fifty-third Annual Reports. Falmouth, 1884 and 5. Presented by the Society.

Royal Dublin Society. Transactions. Parts 7–10. Vol. 3. 1885. Presented by the Society.

Royal Scottish Society of Arts. Transactions. Vol. 11. Parts 1-3. Edinburgh, 1884-5. Presented by the Society.

Royal Society of Canada. Proceedings and Transactions for 1884 and 1885. Vols. 2 and 3. Montreal, 1884 and 1886. Presented by the Society.

Royal Society of New South Wales. Journal and Proceedings for 1884. Sydney, 1885. Presented by the Society.

Russell-Erwin Manufacturing Company. Illustrations of Artistic Bronze Hardware. Presented by the Company.

Rutgers Scientific School. Annual Reports for the years 1871 to 1874; 1876; 1878 to 1881; 1883; 1884. Presented by His Excellency, the Governor of the State.

Safe Deposit Company, The. A Public Necessity. Presented by Mrs. Wm. B. Rogers.

Saffray, Docteur. Les moyens de vivre Longtemps. Third Edition. Paris, 1884. Presented by L. S. Ware.

St. Louis Health Commissioner. Annual Report for 1885–1886. Presented by the Commissioner.

Saint Mary's Falls Canal and Locks, Michigan. Detailed Drawings of. Presented.

St. Paul, Minn. Annual Report of the Health Department for 1884 and 1885. Presented by the Health Officer.

St. Paul, Minn. Proceedings of Common Council for 1883–1884. Presented by the Council.

San Francisco, Cal. Annual Reports of the Health Officer for Fiscal Year ending June, 1883, 1884 and 1885.

San Francisco, Cal. Report of the Special Committee of the Board of Supervisors of. July, 1885. Presented by J. L. Meares, Health Officer.

Sanitary Conventions, Proceedings and Addresses. Kalamazoo, June 1 and 2, 1886. Lansing. Presented by the State Board of Health.

Sanitary Improvement Bonds of Jacksonville, Fla. Report of the Trustees. July 1, 1883, to July 1, 1884. Presented by R. N. Ellis, C. E., Superintendent.